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Life History and Harvest Summaries for Selected Invertebrate Species Occurring off the West Coast of North America

Volume 2: Cephalopods and Crustacea

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LIFE HISTORY AND HARVEST SUMMARIES FOR SELECTED INVERTEBRATE SPECIES OCCURRING OFF THE WEST COAST OF NORTH AMERICA

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ABSTRACT

This report comprises synopses of the biology and human utilization of 15 species of cephalopods, crabs, shrimps, and one species of lobster that are found off the west coast of North America. Included in each species synopsis is information on geographic range, habitat requirements, human utilization (commercial, recreational, and subsistence), management, migration and movements, population characteristics, growth and development, food and feeding, biological interactions, and factors influencing populations. A gazetteer of place names mentioned in the report and a glossary of terms follow the synopses.

The following are the species addressed:

Giant octopus, Octopus dofleini
Red squid, Berryteuthis magister
Market squid, Loligo opalescens
Bairdi Tanner crab, Chionoecetes bairdi
Dungeness crab, Cancer magister
Golden king crab, Lithodes aequispina
Red king crab, Paralithodes camtschatica
Blue king crab, Paralithodes platypus
Northern pink shrimp, Pandalus borealis
Ocean pink shrimp, Pandalus jordani
Coonstripe shrimp, Pandalus hypsinotus
Spot shrimp, Pandalus platyceros
Sidestripe shrimp, Pandalopsis dispar
Ridgeback prawn, Sicyonia ingentis
California spiny lobster, Panulirus interruptus

CONTENTS

INTRODUCTION

From 1984 to 1988, members of the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) helped the National Ocean Service's Strategic Assessment Branch develop a data atlas for marine resources off the west coast of North America. Entitled West Coast of North America Coastal and Ocean Zones Strategic Assessment: Data Atlas, the Data Atlas is a graphic and written summary of important characteristics of marine resources for the study region. It includes descriptions of how marine resources are utilized by humans and the impact of other human activities. A major component of the Data Atlas is the section on living marine resources, which includes life history summaries and associated maps portraying temporal and spatial distributions of the marine resources at various life stages. This living marine resource section of the Atlas is the principal component that AFSC scientists developed. Over 100 species of marine mammals, birds, fishes, and invertebrates are addressed.

Although the Data Atlas is a thorough condensation of the salient points for each species, its format restricts the quantity of information that can be presented. Details on geographic distribution, seasonal movements, life history, or human utilization simply could not be incorporated. Consequently, members from the AFSC's Resource Assessment and Conservation Engineering (RACE) Division, who compiled the information on fishes and invertebrates for the Data Atlas, decided to publish their findings in a less condensed form.

This second volume summarizes information on 15 species of cephalopods, crabs, shrimps, and one species of lobster. The first volume covers the shelled molluscs, the third will cover demersal fishes, and the fourth will cover anadromous and pelagic fishes.

PROCEDURES FOLLOWED IN DEVELOPMENT OF SPECIES SYNOPSES

The species in the Atlas were selected based on a combination of factors: economic importance, ecological significance, and richness of information. Representatives have been selected from a cross section of marine habitats--from the intertidal zone down to the depths of the continental slope and out into the open ocean.

All synopses follow a standard format (Table 1). Among the topics addressed are regional and depth distribution, life history characteristics, human utilization (i.e., commercial, recreational and subsistence harvests), and resource management. The life history information summarizes historical material from the scientific literature through 1986, although more recent sources are occasionally included. References are primarily from original sources, with occasional use of synthesized material when other references were not available.

Information on harvests was obtained from three sources: published literature, computer summaries from resource management agencies, and personal communications with resource managers. Harvest descriptions focus on a series of "baseline" years (1981-83) that were established during the initial drafting of the Data Atlas. Historic summaries are also included when appropriate and more recent catch statistics are provided when available. Catch values for U.S. landings are derived from fisheries statistics publications prepared by the NMFS National Fishery Statistics Program and from state or regional management agencies. Values for Canadian harvests are derived from Canada Department of Fisheries and Oceans annual catch statistics documents and have been adjusted to U.S. dollars unless otherwise indicated. Currency exchange rates for the baseline years are: 1.2000 for 1981, 1.2344 for 1982, and 1.2325 for 1983.

Table 1.--Standard format followed in species synopses.

Common Name, Scientific Name
Other Common Names
CLASSIFICATION
MANAGEMENT
VALUE
Commercial
Recreational
Subsistence
Ecological
RANGE
Worldwide
Within Study Area
LIFE MODE
HABITAT
Type
Substrate
Physical/Chemical
MIGRATION AND MOVEMENTS
POPULATION CHARACTERISTICS
REPRODUCTION
Mode
Spawning
Fertilization
Reproductive Potential
Egg Size
Embryonic Development
Larval Size Range
Juvenile Size Range
Age and Size of Adults
Release of Young (where appropriate)
FOOD AND FEEDING
Trophic Mode
Food Items
Feeding Behavior
BIOLOGICAL INTERACTIONS
Predation
Competition
Symbiotic Relationships
Social Interactions
Community Associations and Interactions
FACTORS INFLUENCING POPULATIONS

Procedures were adopted to condense the text and improve its flow without lessening its content. The references in the synopses are combined into a master list that is numbered sequentially. The number of the reference is cited in the text rather than the author and date. Personal communications are cited in the reference list to eliminate footnotes.

Only common names for life forms are mentioned in the text unless they are unavailable. Common names used for fishes are those recognized by the American Fisheries Society, and common names for invertebrates are those used in extensive publications such as Abbott et al. (1968), Smith and Carlton (1975), and Morris et al. (1980).

A gazetteer for all place names, geographic features, and marine areas is presented in Appendix A. It includes locations mentioned not only in this volume of species synopses, but in the first volume and the two subsequent volumes as well. Appendix B is a glossary of scientific terms.

GIANT OCTOPUS, Octopus dofleini (Wulker, 1910) (271)

(common devilfish, common Pacific, giant Pacific, North Pacific giant octopus (2,124,132,268,271,295))

CLASSIFICATION

Phylum--Mollusca

Class--Cephalopoda

Order--Octopoda

Family--Octopodidae (29,271)

MANAGEMENT

Harvests of this species are monitored by the states and provinces where it is caught. Additionally, octopus has been identified as a prohibited species by the North Pacific and Pacific Fishery Management Councils. This species may not be retained in catches of the groundfish fisheries (11,215,329,350).

VALUE

Commercial--Giant octopus is fished commercially in the North Pacific from northern Japan and California to the eastern Bering Sea (132,276,350). Since the 1950s, giant octopus harvests from this extensive region have averaged about 20,000 metric tons (t) (roughly 10% of worldwide octopus catch), but the vast majority is taken from the western Pacific. Only about 325 t are taken annually from Northeast Pacific waters, mostly (approximately 80%) by Japan in the eastern Bering Sea (12,98). Small domestic fisheries occur off the North American coast from the southeastern Bering Sea to northern California, with about 20-25 t annually harvested from each of the following areas: Alaska (mainly from the Pribilof Islands to Unimak Island, and at the mouth of Cook Inlet), British Columbia (mostly along the north mainland coast and southern

Vancouver Island), and Washington (Puget Sound) (12,58,60,63,329). Giant octopus is fished with a wide variety of gear in Asia (e.g., baited and tangle-hook longlines, gaffs, pots), but is usually taken with crab pots (incidental to crab fishing) or octopus pots in North American waters (271,341). In Japan, where most octopus is marketed, this species is sold as food; small individuals (<10 kg) are sold fresh, and larger, tough-meated ones are sold smoked, dried, canned, or pickled (341). Although some of the U.S. harvest is sold for human consumption, most is used as Pacific halibut bait (117). This species is considered underutilized in North American waters; however, most fishing methods are very labor-intensive and the resulting product is not always internationally competitive (250).

Recreational--This species is of minor importance in British Columbia and Washington (329,350).

Ecological--Giant octopus is the largest octopus in the world and is the most common form along the continental shelf of western North America (2,271).

RANGE

Worldwide--Giant octopus is a temperate North Pacific species that is found from the central China coast to the Bering Sea (possibly further north) and from there to northern Mexico (271).

Within Study Area--This species is found from the eastern Bering Sea and western Aleutian Islands south to northern Baja California (to approximately lat. 30°N) (271). It is common in Puget Sound and uncommon south of Oregon.

LIFE MODE

Eggs are sessile and benthic (29). Young juveniles (up to the age of 1 month) are pelagic; older juveniles and adults are benthic (132,271).

HABITAT

Type--Eggs are sublittoral and occur at depths of 13-50 m (117). Pelagic juveniles are neritic and are found from the surface to 300 m, concentrated in the upper 100 m (167). Small, benthic juveniles occur from the lower intertidal zone to 50 m (132,117). Subadults and adults are found from the lower intertidal zone to 900 m, but mostly at depths less than 100 m (132). Substrate--The eggs are attached to rocks on sandy gravel or rocky bottoms (117,271). After the pelagic phase, small juveniles live under rocks and in crevices on rocky substrate (295). Larger juveniles and adults prefer rocky substrates, but may be found on rock, sand, or mud bottoms (117). Physical/Chemical--This species lives in polyhaline-euhaline waters with salinities greater than 20 ppt. Salinities less than 17 ppt are fatal to larvae. Giant octopus prefers water temperatures between 7 and 15°C (117).

MIGRATIONS AND MOVEMENTS

Seasonal bathymetric migrations of this species in North American waters are not extensively described. Juveniles change their depth distribution semiannually off the coast of Japan (February-April, deep; May-July, shallow; August-October, deep; and November-January, shallow) (198). In Puget Sound, it apparently moves inshore in the winter to depths less than 15 m and offshore in the spring to depths greater than 30 m (341). An inshore migration by mature males and nearly mature females is associated with reproduction (271). After mating, the male returns to deep water and dies, whereas the female repeatedly changes depths until its eggs are laid in shallow waters (see Mating section) (117). During migrations, giant octopus swims or crawls along the bottom at daily rates of up to 4 km (117). There are no along-shore migrations described.

POPULATION CHARACTERISTICS

There are four subspecies of giant octopus: Octopus dofleini dofleini occurs off Japan and Korea; O. d. apollydon is found from the Sea of Okhotsk to the Gulf of Alaska; O. d. martini occurs in waters from British Columbia to Monterey, California; and an undescribed subspecies is present south of there (2,132).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (271).

Mating--Mating occurs from October to December at depths less than 100 m and usually lasts 2-4 hours (117). During mating, the male mounts the female and partially inserts two spermatophores (each is at least 60.0 cm in length) under the mantle into the distal oviducts. Exposure to salt water initiates a chemical reaction which causes the spermatophore to eject a tube of sperm into the oviduct (250). Females are immature during mating and copulate with mature males that are larger than themselves. The sperm is stored inside the female until the ovaries mature (117). Males can fertilize up to 5 females (117).

Fertilization--Internal; takes place as the eggs are laid, usually at least 42 days after mating (117). The eggs are laid into nests throughout the year, but fertilization occurs mostly during winter (132,271).

Reproductive Potential--Giant octopus has a fecundity of 18,000-100,000 eggs per female, but probably no more than 50,000 eggs are actually laid (117). This species is semelparous (i.e., it spawns only once), although males may mate with several females during a spawning season (117). The female guards the nest until the eggs hatch and then dies.

Release of young--Juvenile giant octopus develop directly from the egg with no metamorphosis through a post hatch larval stage. Hatching occurs at night

over a 15-day period for a given batch of eggs (117,341). Hatching probably occurs year-round, though April is the likely time of peak hatching off British Columbia (198).

GROWTH AND DEVELOPMENT

Egg Size--6-8 mm long, 2-3 mm wide (132).

Embryonic Development--Direct and external (271). Egg incubation lasts from 5 to 7 months, depending on water temperature (2300-2700 centigrade degree days required) (117,132). Although young giant octopus do not develop through metamorphic larval stages (271), the miniature adult replicas are planktonic for the first 1-4 months and then settle to the bottom, usually in the spring. They are 50-73 mm total length (TL) (approximately 14.0 mm mantle length (ML)) when they settle (117,132,271).

Juvenile Size Range--Juveniles are 0.7-1.0 cm TL (3.4 mm ML) at hatching and grow to a size of about 61 cm (218,271). Growth rate is very rapid (e.g., up to 9.0 kg in a year off the coast of Japan; up to 3.7% per day for 80 days in rearing experiments) (198).

Age and Size of Adults--Giant octopus matures at age 2-5 years (males earlier than females) and weighs 6-25 kg (15 kg average) (117). Males live longer than females (4-5 years vs. 2-3 years). The largest specimen recorded was 9.6 m (arm-spread) and 272 kg (132).

FOOD AND FEEDING

Trophic Mode--Carnivore (117).

Food Items--Pelagic juveniles eat copepods and amphipods (117). Benthic juveniles and adults consume a wide variety of items including decapod crustaceans (e.g., shrimp and cancrid crabs), fishes, molluscs (e.g., scallops, clams, and abalones), and echinoderms (5,117,132).

Feeding Behavior--Pelagic juveniles are visual feeders and attack prey in the water column in a manner similar to squids. When octopi are first settling to the bottom, their prey is both pelagic and benthic (117). Older juveniles and adults capture prey on the bottom with their arms. The octopus can discharge poison into the water to immobilize shellfish (198). Once captured, the prey is maneuvered into the mouth by the arms. Some prey are ambushed from a rock lair, while large crabs are stalked and captured with a sudden flick of the arms (268). Methods used for catching prey can be somewhat more elaborate. The octopus arches its body over a seaweed bed and suddenly encloses the area in a canopy formed by the arm webbing. The arm tips are then inserted beneath the web to search for food (132). Most feeding occurs during the day (117). Females stop feeding during the extended period of guarding eggs (30) and die (from starvation) after the eggs hatch (143).

BIOLOGICAL INTERACTIONS

Predation--Pelagic juveniles are eaten by marine birds (e.g., puffins). Juveniles and adults are cannibalistic and also are prey for a variety of marine fishes (e.g., spiny dogfish, lingcod, Pacific halibut), marine mammals (e.g., ribbon, spotted, and harbor seals, sea otter, sea lions, walrus, and beluga whale), and minks (30,117,132).

Giant octopus uses several defenses against predation. Ink is expelled when hatching occurs to provide a screen for hatchlings to swim rapidly toward the surface (117). Small benthic juveniles hide under rocks, in crevices, and in empty moon snail shells (117,295). Larger juveniles and adults hide in dens under boulders or in crevices in bedrock (30). The octopus is able to change color to match backgrounds. Ink may be discharged as a "smoke screen" that paralyzes the olfactory sense of predators (180,268). This species also has a venomous bite (5).

Competition--Giant octopus probably competes with other octopus species where their ranges overlap. It is very territorial. In rare cases where two giant octopus are caught in a fishing pot, one will kill and eat the other (198).

Symbiotic Relationships--This species is generally solitary and its movements are secretive. Intraspecific competition for dens may occur. There is generally one individual per den except when two are mating (117,276). Females attend the nest by agitating the eggs and shooting streams of water over them (117,271).

FACTORS INFLUENCING POPULATIONS

Brooding behavior affects survival of young. Since the nest is guarded, mortality during the egg stage is likely to be low. Further, the death rate for newly hatched pelagic "larvae" (juveniles) is probably lower than other planktonic larvae since the young octopuses are large and very active swimmers (198). Still, mortality of planktonic juveniles is probably high through predation and physiological stress. Only about 1% of those hatched reach a size of 10 mm ML (117). Once they have settled to the bottom, their population size is probably limited by the number of suitable dens or lairs on the ocean floor. Hence, introduction of new (i.e., artificial) lairs could increase population capacity (198).

Directed fishing on predators or prey has an effect on its population size. By comparison, this species has been overfished off Japan, but is underutilized in the Northeast Pacific (117).

RED SQUID, Berryteuthis magister (Berry, 1913) (271)

(schoolmaster gonate squid (271))

CLASSIFICATION

Phylum--Mollusca

Class--Cephalopoda

Order--Teuthoidea

Family--Gonatidae (29,271)

MANAGEMENT

Red squid is managed as part of the squid resource by the North Pacific Fishery Management Council, the state of Alaska, and Canada (11,215,350).

VALUE

Commercial--Red squid is fished by bottom trawlers along the continental slope from the Sea of Japan to Cape Navarin in the Bering Sea and to the eastern Gulf of Alaska (279,341). Although red squid is mostly taken incidentally in groundfish fisheries, commercial harvests have been substantial. Harvests sometimes exceeded 9,000 t in the late 1970s, and annually averaged over 5,000 t in North American waters from 1981 to 1983 (36). Most harvests have been by foreign fleets, especially from Japan (88% of harvests) and the Republic of Korea (11%) (36-38,241). Continued reductions and elimination of foreign fishing in the U.S. Exclusive Economic Zone (EEZ) has resulted in smaller harvests in recent years. The 1987 catch of 134 t was primarily caught by Japan (97 t) and most of the remainder by U.S. fishermen delivering catches to Japanese factory ships during joint venture fisheries (241).

Major fishing areas include upper continental slope areas of the eastern Bering Sea, the west and central Aleutian Islands, south of the Alaska

Peninsula (341), and, potentially, waters of British Columbia (39). Harvests occur year-round, but mostly from April to December with concentration from May to July and from September to November (37,38).

Red squid is edible, but because of its large size it must be eviscerated before marketing (11,39).

Recreational--Red squid is not an important recreational species.

Ecological--It is an important component in the diet of many marine mammals in the North Pacific (96).

RANGE

Worldwide--Red squid is a boreal, North Pacific (subarctic-transitional) species that ranges from southern Japan and Korea north to the Bering Strait and south to northern California. It occurs across the North Pacific in mid-ocean south to lat. 43°N (2,11,39,145). It is abundant in the Sea of Japan and off the coasts of the Commander Islands (201,223).

Within Study Area--This species occurs from the Bering Sea and Aleutian Islands south to lat. 43°N off the coast of northern California (96), with a few larvae occurring to the coast of Monterey, California (170). Its range roughly follows that of the subarctic and transitional water masses along the coast (278). It is most abundant in the Aleutian Basin and the northern Gulf of Alaska (223).

LIFE MODE

Eggs are benthic. Juveniles and adults are generally pelagic, whereas spawning is benthopelagic (11,145).

HABITAT

Type--Eggs are bathyal, mostly occurring from 200 to 800 m on the continental slope (271). Young juveniles are neritic-epipelagic and are found in the water column from 0 to 100 m (169). Subadults and adults are neritic-oceanic (epipelagic to bathypelagic) and are found from the surface to 1,000 m (271) and perhaps to 4,600 m (5). Adults are most abundant from 200 to 400 m (201).

Substrate--Eggs are probably laid on soft bottoms.

Physical/Chemical--Red squid lives in euhaline waters at temperatures from less than 1 to 13°C (46), though adults apparently prefer water temperatures from 2 to 4°C (201). This species is tolerant of low oxygen levels and high pressures found at great depths. It also tolerates near-surface conditions.

MIGRATIONS AND MOVEMENTS

Adults migrate to the continental shelf from oceanic waters to spawn (228). Small juveniles probably undertake diel migrations of 50 m, whereas similar migrations in subadults and adults may traverse several hundred meters (5).

POPULATION CHARACTERISTICS

Subpopulations have not been described.

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (271).

Mating--Little is known about the reproductive characteristics of red squid in the region covered in the Data Atlas. Mature red squid is encountered by trawl fisheries from June to October from the northern Kurile Islands to the western Aleutian Islands, usually at depths from 200 to 400 m in the western Aleutians (2,201). Known mating grounds occur in the Sea of Japan and off the Commander and Attu Islands (145); however, since the fishery harvests spawning individuals, spawning probably occurs along the continental slope of the

eastern Bering Sea, Aleutian Islands, and Gulf of Alaska east to Yakutat (341). Spawning possibly takes place from April to November (23,24). Mating behavior is presumably similar to that of other gonatid squids. The male transfers spermatophores to the female with his arms and tentacles extended into the mantle. Spermatophores are stored by the female until egg laying commences.

Fertilization--Internal, occurring as the eggs are laid (271).

Reproductive Potential--There is limited information on fecundity. It is probably about 10,000 eggs per female. Spawning occurs only once.

Release of Young--Uncertain; young probably hatch from May to December at depths of about 200 to 500 m along the continental slope.

GROWTH AND DEVELOPMENT

Egg Size--Undescribed.

Embryonic Development--Direct and external (271). Incubation time of the eggs is apparently about 1-2 months. Juvenile red squid are like miniature adults and, hence, do not metamorphose through a larval phase (271).

Juvenile Size Range--This has not been described. Juvenile males probably range from a few millimeters to about 150-200 mm dorsal mantle length (DML), and juvenile females probably range from a few millimeters to about 250-260 mm (200).

Age and Size of Adults--Red squid lives 1 year and reaches a maximum size of 438 mm TL. Males reach 250 mm DML and females reach 320 mm DML (39,145).

FOOD AND FEEDING

Trophic Mode--Carnivore.

Food Items--Juvenile red squid eats pelagic crustaceans such as calanoid copepods, hyperiid amphipods, and euphausiids. Adults eat small fish and squid (145).

Feeding Behavior--Juveniles and adults feed in the water column. Prey is captured by the tentacles and secured and maneuvered to the mouth by the arms. Capture may be preceded by complex approach and orientation procedures. The time of feeding has not been described.

BIOLOGICAL INTERACTIONS

Predation--Juveniles are eaten by salmonids (228). Subadults and adults are eaten by many predators including sharks, salmonids, giant grenadiers, fulmars, shearwaters, storm petrels, kittiwakes, auklets, murres, murrelets, puffins, northern fur seals, sea lions, harbor seal, spotted seals, ringed seals, ribbon seals, Dall's porpoise, white whale, sperm whale, and goosebeak whales (271). Like other cephalopods, red squid can discharge an ink "smoke screen" when alarmed (268).

Competition--Red squid probably competes with other gonatid squids where their ranges overlap.

Symbiotic Relationships--Symbiotic organisms have not been identified.

Social Interactions--Although abundant in some areas, this species appears to be more solitary than other squids. Little is known about their breeding season and at what times they congregate (39).

Community Associations and Interactions--Red squid is generally taken with shrimp along the continental slope off Japan (278).

FACTORS INFLUENCING POPULATIONS

Directed fishing effort by man on the predators and prey of this species would no doubt affect its population size.

MARKET SQUID, Loligo opalescens Berry, 1911 (271)

(calamar (in Mexico), calamari, California market squid, common Pacific squid, common squid, inkfish, opal squid, opalescent inshore squid, opalescent squid, sea arrow, squid (3,108,132,146,271,320))

CLASSIFICATION

Phylum--Mollusca

Class--Cephalopoda

Order--Teuthoidea

Family--Loliginidae

MANAGEMENT

Market squid is managed by the States of Washington and California and by Canada.

VALUE

Commercial--Market squid is of moderate commercial importance along the west coast of North America and is fished from southern British Columbia to Baja California (12,271). Begun in the 1800s, coastwide harvests since the mid-1960s have usually fluctuated between 7,500 t and 23,000 t, but recent catches have been lower. After a record harvest of over 23,300 t in 1981, commercial landings fell to less than 2,200 t in 1983 and 1,400 t in 1984. Some of these declines may be environmentally related (see FACTORS INFLUENCING POPULATIONS section). [Authors' update: by 1986, catches in California increased to over 25,000 t, of which about 4,500 t was used as live bait (67).]

Principal harvest areas include Monterey Bay (since the 1800s) and waters of the southern California Bight (since the 1960s). Areas near Newport, Oregon, became relatively important in the early 1980s (e.g., 7% of total

catch was taken there in 1983 and nearly 43% in 1984 (59,62,65,177,330)), but again produced insignificant catches shortly thereafter (e.g., 29 pounds in 1987 (323)) (Note: small harvest in 1987 is apparently related to weak market conditions rather than resource abundance (309)). Another important fishing area is off the coast of Mexico at Rosarito, Baja California Norte. The northern part of Báhia Sebastian Viscaino may also be important (127).

Market squid is fished with purse seines and lampara nets. At night in southern California, it is attracted by lights and brailed or pumped aboard the fishing vessels (261). It is fished from October to March off the southern coast of California, from May to October off the coast of central California, and from March to June off the coast of Oregon (59,62,65,67,177,330).

Market squid is sold for bait, fertilizer, food for humans, and pet food (132). The portion sold for human consumption is canned or sold fresh or frozen (12,320). Although considered delicious, most market squid sold for human consumption in the United States is exported (320). Its giant nerve fibers are used in biological labs for neurophysiological research (132). The annual west coast harvest from 1981 to 1983 averaged 13,300 t, with a value to U.S. fishermen of over $3.1 million (208,209). [Authors' update: 1981-86 catches averaged 11,700 t, worth $3 million (210,211).] During the 1970s, the market squid resource was underutilized and considered an untapped major resource of the California Current System (282), but in recent years, market demand has exceeded catch (185).

Recreational--Market squid is taken during the mating season at the surface, where it is attracted to night lights (4,326). It is taken by dip nets, squid lures, herring rakes, and bait-fish jigs (326,329). Although sometimes eaten, most is used as bait (185).

Ecological--Market squid is the only abundant inshore squid along the west coast (132). As prey, it is an important link in the food chain between zooplankton and higher trophic levels in the California Current (95,271). Along with euphausiids, northern anchovy, and rockfishes, it is one of the four major species in this region. Its biomass may equal that of the northern anchovy (197,282).

RANGE

Worldwide--Market squid is a temperate (Oregonian-San Diegan), northeastern Pacific species with a range that lies entirely within the region covered by the Data Atlas.

Within Study Area--It ranges from southeast Alaska to Báhia Magdalena, Baja California Sur, including near Guadalupe Island (131,132) and in Puget Sound (97,327). Its abundance may increase in the northern part of its range during and just after El Niño years (95,97,327). Small juveniles are most abundant from Point Conception to Punta Eugenia (131).

LIFE MODE

Market squid eggs are benthic. Juveniles and adults are pelagic (95).

HABITAT

Type--Eggs are sublittoral at depths of 3-180 m (131). Juveniles are neritic and occur from the surface to 200 m. Small juveniles are concentrated in the upper 15 m (95). Adults are also neritic and occur from the surface and tidepools to 460 m (12,145).

Substrate--Egg capsules are attached to rocks, sticks, or other egg capsules on muddy sand bottoms (132,153).

Physical/Chemical--Eggs and adults occur in euhaline water temperatures from 7.0 to 17.5°C (12,222). Juveniles are found at water temperatures of 12.5 to 20.0°C (131).

MIGRATIONS AND MOVEMENTS

Juveniles are carried from the spawning grounds by currents and adults move inshore to spawn (95).

POPULATION CHARACTERISTICS

There may be more than 900,000 t of this species off California (282). Morphological and electrophoretic studies have not shown that distinct subpopulations exist (131).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (271).

Mating--Market squid mates throughout the year. Mating occurs from December to July (primarily December to March) off the coast of southern California, from April to December (primarily May to June) in Monterey Bay, from July to September in Puget Sound, and from December to September (primarily February to March and August to September) in British Columbia (39,132,271). Mating occurs from 3 to 180 m (primarily at 15 m) over muddy sand bottoms in semiprotected bays (102,131,132). Known mating grounds are numerous and include various locations in British Columbia (near Selwyn Inlet on Queen Charlotte Island, Rivers Inlet, several bays around Vancouver Island, and several bays along the Strait of Georgia); off the California coast at Monterey Bay and at various locations in the Southern California Bight (e.g., around the northern Channel Islands, at Santa Catalina and San Clemente Islands, Point Mugu, Point Dume, Los Angeles Harbor, Newport Beach, Dana

Point, and La Jolla); near South Coronado Island, Báhia Todos Santos, and Báhia de San Quintin in Baja California Norte; and at Báhia San Cristobal, Báhia Asuncion, Báhia San Hipólito, and Báhia Ballenas in Baja California Sur (19,25,95,101,261,323). Mating is most intense at night and occurs sporadically during the day (95). Market squid congregate in groups of 6-8 during mating (180). Some females attract several males, although males initiate mate selection (95,131). Spawning involves complex color displays and tactile behavior. The male and female swim side by side and the male inserts spermatophores into the mantle cavity of the female with its hectocotylized arms. It continues to hold the female during egg laying. After separating, both may mate with other individuals (95,131). Adults do not brood eggs (180).

Fertilization--Internal, occurring a few hours after copulation as the eggs are laid (271,320).

Reproductive Potential--Females lay 20-30 gelatinous egg capsules, each with 200-300 eggs and, hence, may yield 4,000-9,000 eggs (261). Both males and females mate several times with the same or different mates during the spawning season (95). Market squid is semelparous, spawning for one season before death (261).

GROWTH AND DEVELOPMENT

Egg Size--2.0-2.5 mm long, 1.3-1.6 mm wide (95).

Embryonic Development--Direct and external (271). Incubation time of the eggs varies with water temperature and ranges from 12 to 29 days at 16.0°C, to 3 months at 7.0 to 8.0°C (95,271). Hatching occurs at night (95). Juveniles resemble miniature adults and, hence, do not pass through larval phases (271).

Juvenile Size Range--2.5-3.2 mm DML and 5.0 mm TL at hatching to 70.0-140.0 mm DML (95,131,271,329). Growth is rapid initially, but slows as maturity approaches (308).

Age and Size of Adults--Market squid matures at 1-2 years. Sizes at maturity are from 70 to 130 mm DML for males and from 80 to 140 mm for females (95,271,308). Adults live for 2 years, reach a maximum size of 230 mm DML (350 mm TL), and weigh over 190 g (131,146). Males grow to 270 mm TL and females grow to 200 mm TL (132,271). Earlier reports suggest that this species matures and dies at 3-4 years (95).

FOOD AND FEEDING

Trophic Mode--Carnivore (320).

Food Items--Juveniles feed on calanoid copepods, cumaceans, decapod megalopae, and larval fishes (131,158). Adults feed primarily on crustaceans (including euphausiids and mysids), fishes, and squid (including conspecific young) (95,102,131,158,167,320). Diet changes with age and size of market squid. Small squid eat more crustaceans than fishes, whereas adults eat more fish than crustaceans (95).

Feeding Behavior--Juveniles and adults feed primarily in the water column, although adults may consume benthic prey on the spawning grounds (95,158). During feeding, market squid changes color and forms a cone with its arms to hide the tentacles. It then makes short darts at prey and captures them by shooting out the tentacles. Prey is then returned to the open arms and held and eaten. It can capture additional prey with its tentacles while eating (95). Squid generally moves forward by undulating its fins, but can make short darts forward or backward by turning its siphon and expelling water (132,320). It is able to capture prey with the sucker-bearing arms and tentacles, paralyze prey with a neurotoxin, and break apart large or shelled

organisms with a powerful beak (95). Market squid feeds primarily from 20 to 50 m in the water column during the day, but may rise to the surface to feed at night when moonlight is bright or where night lights are present.

BIOLOGICAL INTERACTIONS

Predation--Eggs are eaten by bat stars (Patiria miniata) and little sea urchins (Lytechinus) (146,180). Hatchlings are eaten by curlfin sole (197). Juveniles and adults are eaten by many species of sharks, bony fishes, sea birds, and marine mammals (95,197). Dying squid on the spawning grounds is eaten by sunflower seastars and spotted ratfish (1,95).

Market squid eggs are distasteful to most predators (95). Hatching occurs at night which may reduce predation on hatchlings. Also, newly hatched juveniles quickly swim to the surface and are carried away by currents (95). Juveniles and adults defend themselves against predation by forming large schools (271). Adults are highly maneuverable, capable of quick accelerations. They can discharge an ink "smoke screen," and bite with a powerful beak (131,268).

Competition--Market squid may compete for food with Pacific sardine (95).

Symbiotic Relationships--A polychaete (Capitella ovincola) burrows into the egg capsule and feeds on the gelatinous material (180). Adults occasionally carry larval tapeworms and nematodes (132).

Social Interactions--Juveniles and adults form large schools of up to 400 m long and 30 to 40 m thick (282).

BIOLOGICAL INTERACTIONS

Community Associations--Market squid associate with Pacific herring, Pacific sardines, northern anchovies, Pacific sauries, and chub mackerel (95). In Monterey Bay, they occur at night with northern anchovy and Pacific herring

throughout the bay; with Pacific electric ray, plainfin midshipman, and white croaker inshore; and with Pacific hake (= Pacific whiting) offshore (271).

FACTORS INFLUENCING POPULATIONS

Peak catches follow warming of surface waters after cessation of upwelling (warming also may stimulate spawning) (177). Cannibalism is common and market squid is prey to many species (95,197,271). Post-spawning mortality is high (probably 100%) for both sexes (271).

Climatological changes, such as El Niño phenomena, may also affect squid abundance. For example, the commercial harvest in 1973 was poor following an El Niño event. During the 1982-83 El Niño, squid was not observed in typical spawning areas near the Channel Islands and in Monterey Bay. Because commercial interest in California market squid also decreased during this time, the overall impact of the El Niño event is unclear (58). Market squid was not of commercial interest off the coast of Oregon and in Puget Sound until the early 1980s, and its sudden emergence into catch statistics cannot be clearly associated with that El Niño event (58,66,177,208,209,327). Squid catches are significantly smaller when sea temperatures are low (191), and their abundance off California is generally low during the summer following a strong Davidson Current (114).

ALASKA SNOW CRAB or BAIRDI TANNER CRAB, Chionoecetes bairdi Rathbun, 1924

(Alaskan Tanner crab, Arctic Tanner crab, Bairdi crab, snow crab, Tanner crab (35,48,57,136))

CLASSIFICATION

Phylum: Crustacea

Class: Malacostraca

Order: Decapoda

Family: Majidae (29,45,116)

MANAGEMENT

Bairdi Tanner crab is managed jointly by the State of Alaska and the North Pacific Fishery Management Council (NPFMC). The State Board of Fisheries and NPFMC meet in joint session annually to review the status of the resource and recommendations from state and federal fisheries scientists, industry, and the public. The Alaska Department of Fish and Game is then responsible for day-to-day management of the fisheries with overview by the National Marine Fisheries Service (11,214,215).

VALUE

Commercial--This is an important North Pacific crab that is commercially harvested off the coast of North America in Alaska. It is usually fished with pots from the southeastern Bering Sea and western Aleutians to southeast Alaska. Although initially sought as an alternative harvest to replace king crab during low abundance years, it has been an important commercial species since the early 1970s. The fishery is typically a winter activity (usually after king crab fisheries for regulatory purposes) with 95% of recent (1981-83) harvests occurring from December to April (80% in February-April)

(8-10). The fishing season has a legal starting date (varies from November to February by area) and its closure is based upon factors such as attainment of target harvest levels and the occurrence of molting crab in the population (usually from May to June). Only adult males are harvested (11,214). During the zenith of the fishery, harvests (over 40,000 t annually from 1973 to 1980) focused on the southeastern Bering Sea and around Kodiak Island. A peak harvest of 60,000 t was achieved in 1978 and a peak value was achieved in 1982 at nearly $66 million (8,9). Catches in recent years have declined substantially; the total 1983 harvest of 16,500 t was the lowest in 15 years. Average annual harvests from 1981 to 1983 were 20,500 t (8-10). [Authors' update: 1986 catch was approximately 7,000 t, valued at about $30 million (extrapolated from references 8,10,15).] This decline is probably due to several factors (see FACTORS INFLUENCING POPULATIONS section below).

Important fishing areas for bairdi Tanner crab from 1981 to 1983 include the southeastern coast of the Bering Sea from Cape Mordvinof to Cape Seniavin (harvest was over 16,000 t); from the Alaska Peninsula coast of the Gulf of Alaska from Morzhovoi Bay to Pavlof Bay (2,500 t), near Chignik Bay (31,300 t), and from Cape Nushagak to Cape Douglas (1,700 t); upper Shelikof Strait and the west coast of Kodiak Island (2,700 t); the east side of the Kodiak Island region from Chirikof Island to Portlock Bank (12,000 t); the lower Cook Inlet and Kachemak Bay (3,200 t); the outer coast of Montague Island and Hinchinbrook Entrance into Prince William Sound (1,900 t); and Icy Strait in southeast Alaska (1,000 t) (12).

Before 1976, foreign fleets (Japan and the U.S.S.R.) fished this species in the eastern Bering Sea. However, catches by foreign fleets became substantially restricted after implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976. All directed foreign fishing

for this species was eliminated after 1980. The current fishery is conducted by domestic fishermen.

Subsistence/Recreational--Bairdi Tanner crab is of minor importance (16). In Alaska, noncommercial harvests are defined as "subsistence" or "personal use"; both can be considered recreational (163).

Ecological--It is a dominant epibenthic species on the continental shelf of the eastern Bering Sea and Gulf of Alaska (150). It is also an important prey item.

RANGE

Worldwide--Bairdi Tanner crab is a boreal, eastern Pacific species that is found from the western Bering Sea off the coast of Siberia, to southern Oregon (136,178,288,296).

Within Study Area--It occurs from Nunivak Island in the Bering Sea and Attu Island in the western Aleutians south to Winchester Bay on the Oregon coast (136,178,288). A few specimens have recently been taken in Norton Sound (235).

LIFE MODE

The eggs are brooded on the pleopods of the female (296). Zoeal larvae are pelagic, megalopae are bentho-pelagic, and juveniles and adults are benthic (231).

HABITAT

Type--Larvae are planktonic-neritic and occur in the upper 130 m of the water column, with most found in the upper 60 m (139,159,343). Juveniles and adults are sublittoral-bathyal and occur from 20 to 700 m, but they occur primarily from 50 to 200 m (116,231,248).

Substrate--Juveniles are found on green mud, in fine gray-black sand with shell material, and occasionally in dense epifaunal growths of sponges, hydroids, and bryozoans (148). Adults generally occur on green and black mud or in fine gray-black sand with shells, but may also be found on bedrock or boulders (30,148).

Physical/Chemical--Bairdi Tanner crab occurs in euhaline waters of 30 ppt or greater (231). Larvae are found at water temperatures from 5 to 10°C. Most occur in areas where summer (July through August) temperatures range between -0.5 and 7.0°C (139,231,238,296).

MIGRATIONS AND MOVEMENTS

Juveniles and females are nonmigratory, but males may move in association with mating and feeding (33,288,296). An inshore spawning migration occurs from late winter to early spring in the northern Gulf of Alaska, but has not been documented elsewhere (33,231). Males move up to 359 km in 2 years (straight line distance), but the average net distance between release and recapture 1 year later is 73.3 km (range, 7-87 km) (189). Larvae do not undertake diel vertical migrations (139).

POPULATION CHARACTERISTICS

Discrete, noninterbreeding subpopulations have not been described, although centers of abundance are often separated by regions of low abundance (296). This species and the northern snow crab (C. opilio) hybridize to some extent where their ranges overlap in the eastern Bering Sea (231). Less than 1% of the Tanner crabs in the region of overlap are hybrids (240). The hybrids are genetically and morphologically intermediate and many of the females are nongravid at maturity or have small clutches with many dead eggs (152).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (231).

Mating--This species mates from January to June at depths of 70-90 m throughout their known geographic range (33,231,288,296). During mating, the female apparently attracts the male. [Authors' note: females of other brachyuran crabs excrete a pheromone in their urine; this is assumed but unverified for Tanner crabs.] Primiparous (first spawning) females undergo a final molt during which they acquire secondary sexual characteristics (33). The male grasps the chelipeds of the female with his chelipeds and holds her for up to 14 days (231,296). Females do not molt again for the remainder of their lives (247). During mating, the female is positioned with the sternum facing that of the male. The male extrudes spermatophores into the genital openings of the female where they are stored in sacs (spermathecae). Females extrude eggs within 2 weeks. Females that mated the previous year will hatch that year's clutch of eggs (296), often within just a few hours of a subsequent mating (4). Laboratory experiments have shown that clutches following the first may be fertilized by additional matings or by sperm stored from the first mating. The contribution to reproductive potential from additional matings is not known (163). Stored sperm has been demonstrated to be viable for at least 1 year (247).

Fertilization--Internal, but does not occur during copulation. Sperm stored in the female's spermathecea is used to fertilize eggs as they are extruded (296).

Reproductive Potential--Fecundity varies from 24,000 to 400,000 eggs per female, with about 175,000 eggs at 95.0 mm carapace width (33,139,231). Fecundity is highest at the second spawning (296). Males may mate with more than one female per year and may mate for several years (33,231). Some females mate only once during their lives but may produce a viable egg clutch

the following year using stored sperm (247). Other females mate more than once (but only once in a year) and produce up to three or four clutches in a lifetime (231,296).

Release of young--Larvae are released from March to July off Kodiak Island and from late April to early May in the eastern Bering Sea (139,296,343). They probably are released at mating depths from 70 to 90 m, since any subsequent matings usually occur within 2 weeks of hatching (288,296). Larval release in the eastern Bering Sea appears to occur over a period of 30 to 40 days (140).

GROWTH AND DEVELOPMENT

Egg size--Ellipsoid, 1.0-1.3 mm long, 0.9-1.1 mm wide (123).

Embryonic Development--Indirect and external (33). Incubation time of eggs is about 1 year (particularly for primiparous females) (296). The larvae develop through two zoeal stages and one megalopa stage (33). Larval development takes up to about 120 days, depending on water temperature, and usually occurs during the normal spring plankton bloom (33,231,296).

Larval Size Range--2.5 mm carapace length (CL) at hatching, 6.5 mm at zoeal stage II, and 3.1-3.5 mm (mean, 3.3 mm) as megalopae (139,151,334).

Juvenile Size Range--3.4 mm to 65-140 mm depending on sex and region (33,296).

Size and Age of Adults--Females mature at 4-6 years and males at 5-6 years (231). Females mature at 65-110 mm carapace width (50% at 83-84 mm) and males at 76-140 mm (50% at 105-115 mm) (33,231,296). Females do not molt and hence do not grow after reaching maturity; males molt less than once a year after maturity (231). This species may live for 14 years and reach a maximum size (carapace width) of 110 mm (female) or 190 mm (male) (296). Size at maturity and maximum size usually decrease with increasing latitude because of lower maximum summer temperatures (303); maximum size in southeast Alaska (southern

limit of notable concentrations) is smaller than maximum size in the Gulf of Alaska (163).

FOOD AND FEEDING

Trophic Mode--Primarily carnivorous, but known to be omnivorous (predator and scavenger) (231).

Food Items--Zoeae feed on zooplankton and, to some extent, on phytoplankton (33,139,231). Megalopae feed on detritus and benthic organisms, but also on planktonic prey (33,231). Juveniles feed primarily on molluscs, crustaceans, and polychaetes (33,91,150,231,248). Adults feed on crustaceans (mainly hermit crabs), molluscs (primarily bivalves), polychaetes, plants, detritus, and a wide variety of benthic prey (33,90,91,94,150,231). They do not feed on sea stars (150).

Feeding Behavior--Zoeae feed in the upper 40 m of the water column and megalopae feed in the water column and on bottom (231). Juveniles and adults feed on the bottom (33). The chelipeds of the juveniles and adults are probably used for crushing and extracting prey.

BIOLOGICAL INTERACTIONS

Predation--Larvae are eaten by walleye pollock, yellowfin sole, and surface-feeding birds (139,231). Juveniles and adults are eaten by octopus, shrimp (Lebbeus groenlandicus), red king and Dungeness crab, flatbottom seastars (Asterias amurensis), and a wide variety of fishes, such as Bering and Alaska skates, Pacific tomcod, Pacific cod, shortspine thornyhead, sablefish, numerous sculpins (e.g., yellow Irish lord, butterfly, bigmouth, thorny, plain, great, spinyhead, and blackfin sculpins), dusky and polka-dot snailfishes, searcher, and several flatfishes (e.g., arrowtooth and starry flounders, Pacific halibut, and rex, flathead, Dover, yellowfin, and rock

soles) (33,90,148). Bairdi Tanner crab is cannibalistic. Juveniles hide among sponges for protection, whereas adults are cryptically colored and bury themselves in sediments (248,296).

Competition--Bairdi Tanner crab may compete with red king crab and northern snow crab for food (103,297) and habitat (163).

Symbiotic Relationships--This species is infected by an ascomycete fungus, Trichomaris invadens, which causes a black mat syndrome on the exoskeleton and results in an extensive invasion of hyphae into internal tissues and organs. Black mat syndrome is usually fatal (305). The eggs are parasitized by a polycladid flatworm, and an ectoparasitic leech lays its eggs on the exoskeleton (33). The exoskeleton is frequently encrusted with the ctenostomatan bryozoan, Alcyonidium (75); various barnacles; and tube-dwelling worms (15).

Social Interactions--Bairdi Tanner crab occurs in aggregations composed of individuals of the same sex throughout most of the year (296). The mating behavior has been described above. Males compete for mates.

Community Associations and Interactions--Juveniles in the Gulf of Alaska are associated with sponges, hydroids, chaetopterid and syllid polychaetes, ribbed whelk (Neptunea lyrata), gray shrimp (Crangon communis), and red king crab (248,288). Adults are associated with red king crab, northern snow crab, skates, Pacific cod, walleye pollock, arrowtooth flounder, flathead sole, yellowfin sole, rock sole, and Greenland turbot in the eastern Bering Sea (156,231,292,293).

FACTORS INFLUENCING POPULATIONS

Larval mortality increases if larvae are unable to find food during the critical feeding period after hatching or are transported offshore by currents. Adults are infected by a bacterium which softens the exoskeleton

and causes death. An ascomycete fungus causes the black mat syndrome and is almost certainly fatal (238,306). Predation is probably an important source of natural morality (231). The natural mortality rate for juveniles is about 0.35 (296). The directed commercial fishery removes 40-60% of the males above 140 mm carapace width. Larval (in particular), juvenile, and adult mortality rates would probably increase as a result of oil pollution (231). The dramatic decline in Alaska snow crab abundance in the eastern Bering Sea between 1977 and 1978 is thought to be associated with warming water, but the extent of a temperature effect cannot be verified (236).

DUNGENESS CRAB, Cancer magister Dana, 1852

(coastal crab, commercial crab, common crab, common edible crab, Pacific crab, Pacific edible crab (74,53,107,116,280))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Cancridae (29,45,116)

MANAGEMENT

Dungeness crab is a coastal species. Individual states regulate the fisheries for this crab within their territorial waters and in the adjacent EEZ. Harvests in British Columbia waters are monitored by the Canada Department of Fisheries and Oceans.

VALUE

Commercial--This species has the longest history of commercial exploitation of any crab on the west coast of North America. It is fished commercially with pots in shallow coastal waters from central California to Alaska's eastern Aleutian Islands, with 75 to 90% of harvests occurring within 3 miles of the coast throughout its range (203-209,212). Fishing depths vary by region and range from 4 to 200 m, although most of the crabs are caught between 20 and 80 m (78,80,219). Population abundance appears to be cyclic, although regional variations in harvests may be related to the broad geographic range of the species (242). From 1974 to 1983, annual coastwide landings averaged nearly 17,000 t, with a record U.S. catch of over 27,000 t in 1977 (242). The record value to U.S. fishermen came from the 1983 harvest with an ex-vessel value of

nearly $37 million (209). [Authors' note: harvests during 1987-88 will likely approach historic highs and values will exceed previous records.]

Fishing seasons are usually associated with the biology of the species. In the United States, only adult males are harvested, whereas off Canada, females are also taken (144). Fishing seasons generally start sometime after the crabs have molted and filled out their exoskeletons. Since the molting period varies by region, so do the fishing seasons, with the bulk of each region's harvest usually occurring within 1-4 months of the opening date. Time periods for major harvests are earlier in the year in the Dungeness crab's northern range. Major harvests from December to January occur off the coasts of California, Oregon, and Washington; from October to November in Puget Sound; from July to October off the coast of British Columbia (no closed season); from June to October near Kodiak Island and off the coast of western Alaska; and from May to August off the coast of southeast Alaska and Prince William Sound (245). These fisheries are entirely domestic, with nearly 95% of annual harvests taken from the United States (the remainder is from British Columbia). Annual catches from 1981 to 1983 averaged about 14,800 t, with an ex-vessel value to U.S. fishermen of about $32 million (207-209).

The current important fishing areas are located in numerous regions from the western Gulf of Alaska to northern California and include the Alaska Peninsula coast from Cape Igvak to Cape Douglas (12); the Sitkinak Island to Ocean Bay area south of Kodiak Island (83); Kachemak Bay off lower Cook Inlet (325); the north coast of the Gulf of Alaska from Cape Suckling to Yakutat Bay (12); the central portion of southeast Alaska in northern Sumner Strait, and especially the Stikine River Delta and Duncan Canal Estuary (12,162); British Columbia along the north coast of Graham Island, Chatham and Barkley Sounds, and the Fraser River Estuary (68-70); Bellingham Bay in northern Washington (331) and along the Washington coast from Cape Elizabeth to the Columbia

River, including Willapa Bay and Grays Harbor (219); the Oregon coast (47,175,176); and the California coast north of Cape Mendocino (325).

Dungeness crab is recruited to the commercial fishery by age 4 years in California and at 4 to 5 years in Alaska (324). It is sold fresh, whole cooked or shelled, shelled and frozen, or vacuum packed in cans.

Recreational--Dungeness crab is fished from central California to Alaska by hand, hoop nets, and traps. The sport harvest for the entire study area is not known. An estimate for Puget Sound is about one-third of the total harvest from that area (more than 250 t annually (52)) and 1-2% of the total harvest for the outer coast from Washington to California (an average of about 250 t for 1981-83) (79,242). In Alaska, all noncommercial harvests are defined as "subsistence" or "personal use"; both can be recreational (163). There is no sport harvest in San Francisco Bay, California.

Ecological--Dungeness crab larvae are the most common neritic brachyuran larvae at water depths greater than 30 m off the coast of central California (263). It is the dominant large crab on sublittoral soft bottoms from central California to southern British Columbia.

RANGE

Worldwide--Dungeness crab is a boreal, eastern Pacific species with a range confined to the study area of the Data Atlas.

Within Study Area--It is found from Amchitka Island in the Aleutian Islands and the Pribilof Islands in the Bering Sea to Santa Barbara, California (78,107,335). Previous accounts of its occurrence to Magdalena Bay, Baja California Sur are probably erroneous (107).

LIFE MODE

The eggs are brooded on the pleopods of the female (338). Zoeal larvae are pelagic and megalopae are benthopelagic (263). Juveniles and adults are benthic (263).

HABITAT

Type--Eggs are brooded on the pleopods of the female from shore to depths of 100 m (338,339). Larvae are found from 0 to at least 80 m in the water column and from shore to 280 km. Megalopae settle to the bottom from shore to 60 m, but generally less than 25 m (263,343). Juveniles are found from the intertidal zone to 180 m. They are most abundant at depths less than 18 m, but occasionally are numerous at depths from 90 to 180 m (310,319). Juveniles often occur far into estuaries, whereas megalopae and adults are sometimes found in the lower sections of estuaries, and then only rarely (80). Adults occur from the intertidal zone to 230 m, but are not abundant at depths greater than 90 m (107,116).

Substrate--Juveniles are found on sand and green mud, and are often associated with eelgrass in estuaries (310,319). Adults prefer sand bottoms, but occasionally occur on mud, rocks (rarely), and eelgrass (102,116).

Physical/Chemical--Eggs and adults occur in euhaline waters (263,310). In nature, larvae occur at salinities greater than 32.0 ppt, but can survive to 23.2 ppt in the laboratory (263). Juveniles are mesohaline-euhaline and can survive to salinities as low as 7.0 ppt (310), but are found in high abundance in areas with salinities greater than 20 ppt, and usually above 25 ppt (312).

Eggs can survive at water temperatures from 10.6 to 17.0°C with peak hatches occurring from 10.6 to 13.1°C (263,338). Larvae are found from 7.6 to 16.7°C (262). Juveniles are found in waters from 8 to 18°C. Adults are found from 3.3 to 23.8°C (102,107,310).

MIGRATIONS AND MOVEMENTS

Dungeness crab larvae are carried offshore by surface currents during late winter and spring, and megalopae concentrate inshore after upwelling begins (119). Juveniles may move into estuaries after settling outside as megalopae, although many juveniles settle directly in estuaries (143,319). Juveniles tend to move out of estuaries by fall, probably to avoid the shallow waters during periods of peak rainfall when salinity is reduced (312). Adults move randomly, although there is some inshore movement during the summer off the coast of Oregon (102). Adults usually move very short distances, up to 27 km (219), but they may occasionally move up to 185 km along the coast (304).

Zoeae make diel, vertical migrations. They occur near the surface at night and at depths of 15 to 25 m during the day off the coast of California (263). They occur at depths of 0 to 40 m at night and at depths of 0 to 60 m by day near Kodiak Island (343). Megalopae in northwestern British Columbia waters are most abundant in the upper 25 m of the water column and concentrate in the neuston layer at dawn and dusk (40). Juveniles move intertidally at night during high tides (311).

POPULATION CHARACTERISTICS

Although tagging studies have suggested several subpopulations, electrophoretic studies have not yet identified discrete subpopulations (102,304).

REPRODUCTION

Mode--Sexual, separate sexes (one case of hermaphroditism), oviparous (107).

Mating--Dungeness crab mates from March to June in California and from April to September off the coast of British Columbia (107,337). Studies of other crab species suggest that for mating, the female may attract the male with pheromones. The male grasps the female and holds her with her ventral surface

facing his for several days. When the female is ready to molt, the male allows her to turn over. The female molts within a basket formed by the male's legs as it assists the female in shedding her old exoskeleton. After mating, the female is turned over on her back and the male inserts his abdominal flap within hers. As his gonopodia are inserted into her spermathecae, spermatophores are released. The postmating embrace may last for 2 days (268).

Fertilization--Internal (268). After mating, the female stores the sperm for several months. The eggs are fertilized as they are extruded from September to December (107). Sperm can be stored for 2.5 years (81). The female must be partially buried for the egg mass to form (338). Egg-carrying females are often fully buried in the substrate (143).

Reproductive Potential--Dungeness crab produces 700,000-2,500,000 eggs per female, with fecundity increasing with size (102). Females spawn once a year (although they may mate less often). Males may mate more than once per year (81,338). Egg extrusion is from October to April (143).

Release of Young--Larvae are released over a 2-week period from December to mid-April (34,107,163). At unseasonally warmer temperatures, hatching may occur earlier (263). From Washington to California, eggs are hatched from shore to depths of 100 m (but not in bays or estuaries) (263,310,339); however, hatching may occur in deeper parts of bays in British Columbia and Alaska (143).

GROWTH AND DEVELOPMENT

Egg Size--0.4-0.6 mm, but may be smaller at higher water temperatures.

Embryonic Development--Indirect and external (102). Incubation time varies with water temperature, ranges from 64-128 days, and occurs sometime from late September to February (102,107). Ovigerous females do not occur in estuaries

such as San Francisco Bay, California, or Grays Harbor, Washington (although they have been seen in the outer part of Willapa Bay, which is adjacent to Grays Harbor (219)) (263,310). The larvae pass through five zoeal stages and one megalopa stage (102). The larval period lasts from 3 to 5 months, usually about 105-125 days, and occurs from late November to September (102,143,263). Higher temperatures can shorten the larval period (263).

Larval Size Range--2.5-11.0 mm TL (263)

Juvenile Size Range--11-93 mm CW (carapace width) for females and to 140 mm for males (143,263,310).

Size and Age of Adults--Dungeness crab matures at 1-2 years (61). Females mature at 100-105 mm (carapace width) and males at 93-140 mm (143,310). The species lives up to 10 years and reaches a size (carapace width) of at least 170 mm for females and 232 mm for males (116,163,268). Older reports suggest larger sizes (up to 330 mm (180)); early carapace measurements, however, often included the 10th anterio-lateral spines (163).

FOOD AND FEEDING

Trophic Mode--Carnivore (153).

Food Items--Larvae eat zooplankton and phytoplankton (85). Juveniles eat a wide range of benthic organisms, but primarily polychaetes, bivalves, barnacles, and crangonid shrimp (39,311,319). The prey of adults consists of fish, bivalves, and crustaceans (30,39,93,102,107,111).

Feeding Behavior--Larvae feed in the water column and juveniles and adults feed on the bottom. Juveniles and adults crush or chip open bivalve shells with their chelipeds (167). Juveniles are nocturnally active and move intertidally at night to feed (311).

BIOLOGICAL INTERACTIONS

Predation--Dungeness crab eggs are eaten by a nemertean, Carcinonemertes (338). The larvae are eaten by fishes, including Pacific herring, Pacific sardine, and salmon (107). Major predators of planktonic megalopae include coho and chinook salmon. Predators of juveniles include numerous fishes (e.g., brown smoothhound, big skate, green sturgeon, white sturgeon, Pacific tomcod, starry flounder, leopard sharks, bat rays, copper rockfish, kelp greenling, Pacific staghorn sculpin, cabezon, white croaker, pile perch, white seaperch, rubberlip seaperch, wolf-eel, Pacific halibut, rock and English sole), octopus, crabs, the sea star (Pisaster brevispinus), and sea otters (161,264). Dungeness crab is also cannibalistic (264).

Juveniles and adults bury themselves in the sand for protection or run away when alarmed (280).

Competition--Not described. Dungeness crab probably competes with other Cancer crabs where they occur together.

Symbiotic Relationships--Filamentous bacteria, hydroids, nematodes, nemerteans, polychaetes, and copepods live in Dungeness crab egg masses (338). Megalopae are found on neustonic siphonophores (e.g., Velella) and on jellyfish (107,263). Juveniles sometimes occur in ghost shrimp burrows in the intertidal zone (311). An archaeobalanid barnacle grows on the exoskeleton of the adult (212).

Community Associations and Interactions--Zoeae are associated with other plankton including calanoid copepods (Rhincalanus nasutus and Pseudocalanus spp.), hyperiid amphipods (Parathemisto pacificus), and pygmy Cancer crab larvae,(119). Small juveniles are associated with eelgrass (310).

FACTORS INFLUENCING POPULATIONS

Dungeness crab abundance is influenced by a variety of factors, including climate, predation, and pollution. Warm water years in the southern parts of its range decrease crab fecundity and increase mortality of eggs, larvae, and juveniles (337). Levels of predation on the zoeae and megalopae of Dungeness crab may be important in determining year class strength (263,264). Survival of incoming year classes may be adversely affected by a high abundance of older crabs, either through cannibalism, species competition, or both (41). This hypothesis is suggested by the 8-11 year cyclic abundance in southern areas of its distribution. A high abundance of adult crabs might result in poor survival of incoming year classes, which in turn would result in a low population of legal-sized crabs about 4 years later. The opposite would be true during years of low adult abundance (242). Other authorities suggest a need for substantial numbers of large (185-215 mm) "breeder" males to assure good reproductive success (163).

The impact of predation by sea otters on the crab population is substantial in certain regions of Alaska. For example, in Orca Inlet in Prince William Sound, the arrival of large numbers of sea otters in recent years has resulted in an annual consumption estimate for sea otters of as many as 370,000 Dungeness crabs (106). This has reduced crab populations to levels too low for commercial or subsistence harvests. Since the otter is a federally protected species, it is likely that prohibition of otter harvests and commercial or subsistence harvests of Dungeness crab will remain in conflict (161).

Pesticides and the side effects of logging are two sources of pollution that affect the population. The use of pesticides such as Sevin to control organisms that foul oyster beds kills crabs either by direct contact or by affecting the clams that the crabs eat (50). Certain activities associated

with logging in coastal regions of southeast Alaska can affect reproductive success. Decomposing bark accumulates on the bottom of the waters where logs are rafted for transport to mills. Chemical changes associated with these substrate alterations are a likely cause of reproduction abnormalities (e.g., smaller egg clutches) (2,78,100).

Whatever factors affect Dungeness crab populations, it is strongly suggested that year class strength is established during egg and larval stages (113).

GOLDEN KING CRAB, Lithodes aequispina Benedict, 1894 (116)

(brown king crab, deepwater crab, deepwater king crab (11,29,233)

CLASSIFICATION

Phylum: Crustacea

Class: Malacostraca

Order: Decapoda

Family: Lithodidae (29,45,116)

MANAGEMENT

Within Alaska, management policy is determined jointly by the State of Alaska and the North Pacific Fishery Management Council. All crab fisheries are managed by the Alaska Board of Fisheries and the Alaska Department of Fish and Game (ADF&G). The Alaska Board of Fisheries (a Governor-appointed group) considers regulatory changes proposed by the public or by ADF&G, receives testimony concerning proposals, and decides on regulatory changes. The Division of Commercial Fisheries of ADF&G is primarily responsible for golden king crab management, although in some regions the Division of Subsistence may also bear some of the responsibility. This Division is that part of ADF&G that deals with harvests of fish and game for personal use as food, rather than for recreational or commercial purposes. Subsistence utilization of fish and game has highest priority in resource allocation, followed by commercial and then recreational use (230). Harvests of golden king crab in British Columbia are not significant and are not reported separately from other crab catches, such as that of Dungeness crab (144).

VALUE

Commercial--Golden king crab is fished commercially with pots from the eastern Bering Sea and Aleutian Islands to southeast Alaska. Fisheries for this species have expanded rapidly in recent years as a result of the substantial decline of the red king crab resource. Annual harvests expanded from only 520 t in 1981 to a record 5,800 t in 1983 (with an ex-vessel value to fishermen of nearly $40 million) (8-10). Most of this increase occurred in the Aleutian Islands where catches jumped from about 200 t in 1981 to 5,100 t 2 years later. In contrast with this dynamic situation, a fairly small but constant fishery has occurred in southeast Alaska with relatively minor catch fluctuations in recent years (260-370 t annually, 1981-83) (8-10).

Important fishing areas in recent years include waters throughout the Aleutian Islands, but especially east of Agattu and Kiska Islands, on Petrel Bank near Tananga Pass, in Seguam and Amukta Passes, and in Icy Strait and Frederick Sound in southeast Alaska (12,16). Other areas include outer shelf and slope waters of the southeast Bering Sea from the Pribilof Islands to Zhemchug Canyon, off Albatross Bank and in Shelikof Strait in the Kodiak Island area, in Prince William Sound, and in northern southeast Alaska from Glacier Bay and Lynn Canal to Ernest Sound (12). [Authors' update: harvests have remained substantial, at least through 1985. The 1985 catch was 3,675 t, worth $14.2 million. This is 50% of the total king crab harvest (14).]

Harvests are restricted by sex, size (adult males only), and quota, and sometimes by season. Fishing can occur year-round, but most catches are taken from November to March in the Aleutians and from February to April and October to November in southeast Alaska (8-10,13-16). As with other crab harvests off North America, domestic fishermen are the only harvesters.

Recreational--Golden king crab is not fished recreationally.

Ecological--It is probably an important scavenger on the continental slope of the North Pacific and is important as a nest site for Careproctus snailfishes (see Symbiotic Relationships).

RANGE

Worldwide--The golden king crab is a boreal, Pacific species that is found from Hyuganada, Kyushu Island, Japan, to Navarin Canyon in the Bering Sea and south to southern Vancouver Island, British Columbia (56,130,190,303). It is also found in the Sea of Okhotsk (270).

Within Study Area--It occurs from Navarin Canyon in the Bering Sea and Stalemate Bank and Bowers Ridge in the Aleutian Islands to Ucluelet and Sidney Inlets on Vancouver Island (56,190). It is most abundant in areas of the western Aleutian Islands; in Pribilof and Zhemchug Canyons in the Bering Sea; and in Icy Strait, Chatham Strait, Frederick Sound, and Stephens Passage in southeast Alaska. Other areas of occurrence include the southern coast of the Kenai Peninsula, Prince William Sound, most inside waters of southeast Alaska from Glacier Bay and Chilkoot Inlet (northern Lynn Canal) south to Ernest Sound (12), and Observatory Inlet, British Columbia (16). It also occurs in the central Gulf of Alaska on Patton, Surveyor and Dickens Seamounts (137).

LIFE MODE

Eggs are brooded on the pleopods of the female. Larvae are pelagic (303). Juveniles and adults are benthic (233).

HABITAT

Type--Larvae are probably neritic-lower epipelagic and are not found in the upper 50 m of water (303). In the Aleutians and eastern Bering Sea, juveniles and adults are sublittoral-bathyal and are found at 50-900 m (233,291,303) with about 95% occurring between 350 and 600 m (303). The depth distribution of golden king crab in southeast Alaska is undescribed, but in the fjords of nearby British Columbia, bathymetric distribution (within its depth range of 51-402 m) is related to sexual maturity and health. Most juveniles occur at depths less than 150 m (especially 50-100 m). Adult males occur from 101 to 150 m and adult females occur from 151 to 250 m. Parasitized crabs are found between 251 and 400 m (see FACTORS INFLUENCING POPULATIONS) (290). Females undertake bathymetric migrations associated with spawning (291,303).

Substrate--Juveniles and adults occur on mud, sand, cobble, and rocky or bouldery areas that often have corals (233,270).

Physical/Chemical--All life history stages occur in euhaline waters of 33.0 to 33.8 ppt (270). Juveniles occur in water temperatures of 0.2 to 1.0°C. Adults and eggs in water temperatures of 0 to 5°C (most at 1.5-2.0°C) (190,233,270). Adults are found in waters of 2 ml/l oxygen (270).

MIGRATIONS AND MOVEMENTS

Information about movements and migrations is scant. In British Columbia fjords (perhaps elsewhere), these crabs display the following seasonal, onshore, ontogenetic, and migrational characteristics: (a) concentrations of juveniles in shallow waters (<100 m); (b) molting, mating, and egg extrusion in slightly deeper waters, although still in relatively shallow waters; (c) downward migration of incubating females, whereas adult males tend to remain in shallower water; (d) hatching and larval release at depth, with post-spawning recovery in deep water; and (e) eventual upward migration by females

to molting and mating grounds in shallower, fjordic depths to begin a new cycle (290). Similar movements may occur on the continental slope in Alaskan waters, although the depths occupied during each period are probably deeper.

POPULATION CHARACTERISTICS

Population structure is not well described. Fjords in southeast Alaska and British Columbia may contain isolated populations (233,291).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (182,233).

Mating--As a population, golden king crab mates continuously throughout the year at depths of 50-150 m (291). The male holds the chelipeds of the female from 3 to 7 days, at which time she molts. The male then recaptures the female and holds her chelipeds. The female presses her body on the bottom and extrudes eggs onto her abdomen. The male then sheds spermatophores onto the eggs (182). Because the reproductive biology of this species varies by locale, seasonal and aseasonal reproductive characteristics must be assessed on a site-specific basis (290). The mating period in western Alaska is protracted. Grasping pairs are seen from February to May, July, and probably December (237). There may be seasonal peaks for various areas. Females of a given reproductive state may congregate (237).

Fertilization--External and occurs at 50-150 m (233,291).

Reproductive Potential--Fecundity increases with size and ranges from 5,000 to 30,000 eggs for a female with a carapace width of 160 mm (190,303). Fecundity is greater in the north and the overall fecundity is about an order of magnitude smaller than for most lithodid crabs (182,190,303). For example, a 120 mm (CL) golden king crab female carries an average of 11,330 uneyed

embryos, a red king crab carries 151,260 (120), and a blue king crab carries 150,440 (300). Each crab probably spawns once a year (182).

Release of young--Larvae can be released throughout the year (8). In southeast Alaska most hatching occurs in the spring, but in the Bering Sea and Aleutian Islands, most occurs from July to October (190). They are probably released between 150 and 250 m (291). There is an appreciable time lag between the hatching and the extrusion of a clutch of eggs (289).

GROWTH AND DEVELOPMENT

Egg size--2.2-2.4 mm (uneyed) (303).

Embryonic Development--Indirect and external (182). Incubation time of eggs is about 1 year (233). The larvae pass through five developmental stages (122).

Larval Size Range--6.8-7.7 mm to 5.2-6.3 mm (decrease is due to a change in morphology) (122).

Juveniles Size Range--5.0-6.0 mm to 92.0-140.0 mm (122,190,303).

Age and Size of Adults--Golden king crab matures at 92-140 mm carapace length (190,303). Maturity occurs at a larger size in the south (111 mm females, 130 mm males) than in the north (98 mm females, 92 mm males) (303). Maximum size for females is 192 mm and 220 mm for males (233). Maximum age is unknown.

FOOD AND FEEDING

Trophic mode--Omnivore, scavenger (233)

Food items--Golden king crab primarily eats brittle stars, sponges, and plant material; other items include naticid snails, poromyid and lyonsiid clams, polychaete worms, amphipods, and fishes (57,318).

Feeding behavior--Golden king crab feeds on the bottom and probably does not feed during mating (182,288).

BIOLOGICAL INTERACTIONS

Predation--Larvae are probably eaten by chum and pink salmon (182). Juveniles and adults are eaten by octopus and Pacific halibut (182,291). The large size and spiny body probably provide protection against predation for nonmolting adults.

Competition--Golden king crab probably competes with red king crab where their distributions overlap on the outer shelf and upper slope.

Symbiotic Relationships--The hard exoskeleton provides a substrate for sessile sponges, serpulid polychaetes, barnacles, and bryozoans. Snailfishes (Careproctus spp.) lay their eggs in the branchial chambers of this crab and they remain there until hatching (233). A fish leech, Notostomus cyclostomata, also lives commensally on the crab (291).

Social Interactions--Mating behavior was described above. Other social interactions have not been described.

Community Associations and Interactions--Golden king crab is associated with deepwater Tanner crabs (Chionoecetes angulatus and C. tanneri), giant grenadiers, rockfishes, shortspine thornyhead, sablefish, blacktail snailfish, twoline eelpout, and Greenland turbot (233,288,292).

FACTORS INFLUENCING POPULATIONS

Golden king crab has low fecundity and late maturation (190). It is infected by viruses, bacteria, and dinoflagellates, but the effects of these organisms are unknown. It is also infected by an unidentified microsporidian with lethal consequences and is parasitized by the rhizocephalan barnacle, Briarosaccus callosus (193). This rhizocephalan causes degeneration of the gonads and castration and affects somatic growth (apparently size and weight in males but not in females) (44,193,289). Adverse effects on reproductive organs certainly could result in a substantial effect on recruitment.

In addition to direct fishing mortality, there may be a high indirect mortality because it is the most common incidental catch of the king crabs in foreign trawler and long-liner catches (233).

RED KING CRAB, Paralithodes camtschatica (Tilesius, 1815) (103,116)

(Alaska king crab, Kamchatka crab, Kamchatkan stone crab, king crab (116,182,288))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Lithodidae (29,45,103)

MANAGEMENT

Within Alaska, management policy is determined jointly by the State of Alaska and the North Pacific Fishery Management Council, and all crab fisheries are managed by the Alaska Board of Fisheries and the Alaska Department of Fish and Game (ADF&G). The Alaska Board of Fisheries (consisting of members appointed by the Governor) considers regulatory changes proposed by the public or by ADF&G, receives testimony concerning proposals, and decides on regulatory changes. The Division of Commercial Fisheries of ADF&G is primarily responsible for king crab management, although in some areas of the state, the Division of Subsistence may also bear some of the responsibility. This Division is that part of ADF&G that is assigned to deal with harvests of fish and game for personal use as food rather than for recreational or commercial purposes. Subsistence utilization of fish and game has the highest priority in allocating resources, followed by commercial and then recreational use. For red king crab, this is only important in northern areas of the Bering Sea such as Norton Sound (230). King crab harvests in British Columbia are not significant and are not reported separately from other crab catches, such as Dungeness crab (144).

VALUE

Commercial--Catches of this species make up the vast majority of king crab harvests in North American waters (traditionally more than 85% of total catch), and it is one of the most valuable shellfish resources in the world (8-10,234). It is fished commercially with pots in the southern Sea of Okhotsk off Asia and from northern British Columbia to Norton Sound off North America (103,144). [Authors' note: British Columbia harvests are very minor, only a few tons annually.] Most harvests in North America come from Portlock Bank in the northwestern Gulf of Alaska, through the Aleutian Islands, and into the Bering Sea, but primarily from near Kodiak Island (record harvest: 40,000 t in 1966) and in the southeast Bering Sea (record harvest: 79,000 t in 1980). Annual catches have been as high as 89,000 t (1966) and worth as much as $181 million to U.S. fishermen (ex-vessel value, 1980) (7,216). [Authors' note: the value is derived from a combination of landings values listed in ADF&G statistics for "King, red" and "King, general." In some areas, especially Kodiak, red king crab landings have been listed in the category "King, general", even though they traditionally dominant king crab landings in that area, and are likely the only king crab species landed prior to the mid 1980s. Our estimated 1980 value reflects this factor.]

Fishing seasons take place after crabs have molted and filled out their exoskeletons, and the fisheries concentrate on adult males that are large enough to have spawned at least once. The seasons vary by region, but generally the times are late July in Norton Sound, August through September in Cook Inlet, September through January for Kodiak Island and Alaska Peninsula regions, September through October in the southeastern Bering Sea, and November through February in the Aleutian Islands (8,10). There was a substantial foreign fishery in U.S. (Bering Sea) waters until the implementation of the MFCMA in 1976.

Populations are cyclic and current stocks are at all-time lows: the 1983 harvest of 1,313 t was the lowest since detailed statistics were collected in 1953. Current fisheries focus on small areas in comparison to the extensive regions fished during high-catch years. Although several areas have remained closed since 1983, commercial harvests have steadily increased to present levels (5,488 t for 1986-87 in the westward region of Alaska (16)). Total catch for 1985, the most recent statewide figures, was 2,436 tons valued at $14.9 million (14). Causes for the currently depressed population size are not certain but are related to a variety of factors (see FACTORS INFLUENCING POPULATIONS below).

Recreational--This species is important in catches only in the vicinities of coastal Alaskan communities such as Kodiak, Homer, and Juneau. Throughout Alaska it is caught by a variety of methods including pots, hoop or ring nets, and scuba.

Ecological--It is a major portion of the epibenthic crustacean biomass in the eastern Bering Sea (149).

Subsistence--Red king crab is taken for subsistence purposes in western Alaska waters, particularly by residents of Nome along the north coast of Norton Sound. Over 23 t were harvested by subsistence fishermen through the winter ice on Norton Sound between 1977 and 1981 (6).

RANGE

Worldwide--Red king crab is a boreal, Pacific species that ranges from near Tsushima Island between Japan and Korea, and Vancouver Island, Canada, north to Point Barrow, Alaska (103,179,349). It is not found in the western Sea of Japan or western Sea of Okhotsk (103), is rare in the western Bering Sea (288), and occurs in insignificant amounts north of Norton Sound (349).

Within study area--It is found from Kotzebue Sound, Alaska, south through the eastern Bering Sea (mostly east of long. 166°W), and along the continental shelf from Attu Island in the western Aleutians, to Vancouver Island, British Columbia (103,144,349).

LIFE MODE

Eggs are brooded on the pleopods of the female. The zoeal larvae are pelagic, whereas the megalopal larvae, juveniles, and adults are benthic (103,234).

HABITAT

Type--Egg clutches remain attached to the females' pleopods throughout adult depth range (103). Zoeae are found from the surface to depths of at least 80 m (183,343), whereas earlier zoeal stages occur at shallower depths (103,317,343). Megalopal larvae and young juveniles (<40 mm CL) are found from the lower intertidal zone to depths of 50 m (30,290). Subadults and adults are seasonally found from the lower intertidal zone to 366 m (56,290), but mostly at depths less than 200 m (<100 m in the Bering Sea) (344). Adult males occur in deeper waters than juveniles or females (72,234).

Substrate--Megalopal larvae and very young juveniles occur solitarily among seaweed, sponges, hydroids, attached colonial invertebrates, rocks, and detritus (183). Juveniles (>15 mm CL) form large aggregations called pods and occur in hard- or soft-bottom areas, whereas subadults and adults are found on a variety of substrate from mud to rocks (103,166,234).

MIGRATIONS AND MOVEMENTS

Adults perform seasonal bathymetric migrations associated with molting, reproduction, and feeding. They move inshore to 30-60 m from February to June for molting and mating and offshore to 80-366 m from June to October for

feeding and overwintering (31,56,182,234,235,288). In Gulf of Alaska waters, pods of juveniles are found up to the shoreline during summer, but move to deeper water in fall and winter (31). It is assumed that seasonal distribution varies because of the red king crab's response to water temperature (56). In the northern extremes of its distribution (e.g., Sea of Okhotsk and Norton Sound), migrations are northerly in the spring and southerly in late summer (103,234). In British Columbia, red king crab moves into deep water during summer to avoid warm temperatures inshore (56). Adult males can move up to 556 km (300 nautical miles; straight line distance) in less than 1 year in the northwest Pacific (183), and up to 427 km in the eastern Bering Sea (286), but elsewhere males do not move as far. For example, movements in the Gulf of Alaska are more restricted because the continental shelf is frequently interrupted by submarine canyons or troughs; movements are from coastal bays to adjacent offshore waters (256). Daily rates of movement are as much as 13.1 km/day for males and 10.4 km/day for females (183).

POPULATION CHARACTERISTICS

Discrete subpopulations occur throughout the range; as a result, red king crab is managed as separate stocks in Alaskan regions such as Norton Sound, the southeastern Bering Sea, the western Aleutian Islands, Dutch Harbor and the eastern Aleutians, the south coast of the Alaska Peninsula, Kodiak Island, Cook Inlet (Kachemak Bay), Prince William Sound, and southeast Alaska (11). There is no direct evidence of stock intermingling, although passive current drift and a rather protracted early life history could allow larvae hatched in one locality to settle on the bottom a considerable distance away and possibly contribute to the productivity of another population (103).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (182).

Mating--Mating occurs (as a population) from April to June at depths less than 100 m (usually less than 50 m) along the coast or in bays throughout most of its range (257,258). Some specific locations include Norton Sound, in Bristol Bay from Amak Island to Port Moller, around Kodiak Island, and several other locations as far south as Queen Charlotte Island and the northern, coastal mainland of northern British Columbia (56,103,234). Males mate with females smaller than themselves. The male grasps the chelipeds of the female with his chelipeds. This grasp may last from 1 to 16 days. During that time, the female molts and the male regrasps the female and bends her underneath him. The male then extrudes spermatophores and passes them over the eggs on the pleopods of the female with the very small fifth pair of pereiopods that are usually hidden beneath the carapace (257).

Fertilization--External (258).

Reproductive Potential--Fecundity increases with size and ranges from 20,000 to 445,000 eggs per female (120,270). Females mate once per year, but males may mate with several females during a mating season (258). In controlled experiments, males mated up to 13 times, although reproductive success rapidly dropped after 6 (259).

Release of young--Larval release occurs between February and June, generally within a month of the next mating (103,234). The timing of release is temperature dependent. Larvae presumably are released at depths less than 100 m where mating occurs (182,234).

GROWTH AND DEVELOPMENT

Egg size--Ellipsoidal, 0.82 mm x 0.71 mm (183).

Embryonic development--Indirect and external (182). Incubation time is from 11 to 13 months (103,235,257). After hatching, larvae pass through four zoeal stages and one megalopal stage (183). The larval stage lasts from 49 to 100 days, depending upon temperature (183).

Larval Size Range--4.6-6.8 mm TL (103).

Juvenile Size Range--0.5 mm to 60-105 mm CL, depending on sex and region (103,349).

Age and Size of Adults--Red king crab starts maturing at 5 years for males and 5.5 years for females (103). Males begin to mature at 85-95 mm CL and females at 60-105 mm (103,349). This species lives for a maximum of 25 years and reaches 11.8 kg (30,31). Females reach a maximum carapace size of 195 mm (length) by 213 mm (width), whereas males reach a larger size of 227 mm by 283 mm (116). A large king crab with its legs extended can measure 150 cm across (30).

FOOD AND FEEDING

Trophic Mode--Omnivore the first year and more carnivorous later. The red king crab is both a predator and a scavenger (187).

Food Items--Zoeae feed on pelagic diatoms and crustacean larvae (183). Megalopal larvae feed primarily on bryozoans (183). Juveniles feed largely on diatoms, foraminiferans, hydroids, polychaetes, snails, nutclams, ostracods, and echinoderms (103,182). Adults eat a wide variety of benthic prey, although molluscs (especially nutclams), echinoderms, crustaceans, and polychaetes make up the largest part of their diet (88,91,182,183,192). Brittle stars are eaten to replace calcium lost during molting (72).

Feeding Behavior--Red king crab zoeae feed in the water column, and megalopal larvae, juveniles, and adults feed on the bottom (234). Adults use chelipeds to excavate pits in the soft bottom to capture prey, to crush mollusc and sea

urchin shells, and to break off rays of seastars (31,298). Prey is taken from hard and soft bottoms (298). Juveniles are diurnally active; diel behavior of adults has not been described (298). Red king crab does not feed during spawning season (182).

BIOLOGICAL INTERACTIONS

Predation--Red king crab eggs are eaten by the nemertean worm, Carcinonemertes (336). The planktonic zoeal larvae are eaten by pink and chum salmon (182). Megalopal larvae and small juveniles are eaten by the Korean horsehair crab (Erimacrus isenbeckii), greenlings, red Irish lords, and yellowfin sole (103,112,257). Larger juveniles and adults are eaten by octopus, Pacific cod, Pacific halibut, and sea otters (91,103,234,235). Fish predation on large juveniles and adults occurs mostly during molting periods (235).

Small juveniles have long spines and hide in rocks, algae, and debris for protection (103,298). Older crabs are protected from predation by their hard, spiny shells and large size, but are susceptible during molting. Adults find shelter in depressions on the bottom (103,182).

Competition--Red king crab probably competes with seastars, blue king crab, snow (Tanner) crabs, Pacific cod, rex sole, flathead sole, yellowfin sole, rock sole, and Alaska plaice (103,234,298). It is much slower and less mobile than the fishes (103).

Symbiotic Relationships--The exoskeleton provides a substrate for hydroids, serpulid polychaetes, barnacles, and bryozoans (166). Fish leeches and their eggs are found attached to the crab's body. The lumpsucker Eumicrotremus pacificus may attach to the carapace (182).

Social Interactions--Juveniles less than 15 mm CL are solitary (298). Above that size, juveniles of 2 or 3 years (in the Kodiak area) form pods of up to 6,000 crabs (50 deep) from the intertidal zone to 30 m (257). Adults form

spawning aggregations of both sexes, but after spawning the sexes segregate for the rest of the year (183,288,333). Mating behavior has been described above.

Community Associations and Interactions--Megalops and juveniles are found in association with sponges, seastars, hydroids, bryozoans, and tunicates (103,235). Adults are usually abundant where polychaetes, bivalves, and brittle stars are abundant (234). It is also associated with the Bairdi Tanner crab, Myoxocephalus sculpins, Pacific sandfish, starry flounder, yellowfin sole, rock sole, longhead dab, and Alaska plaice (156,288,292,293,349).

FACTORS INFLUENCING POPULATIONS

The greatest mortality occurs in the larval phase, particularly during the first zoeal stage between yolk absorption and first feeding (103). [Authors' note: in a western Pacific study, only about 3.6% of the eggs hatched survived to become megalops (183).] Natural mortality in adults results from spawning senescence, predation, parasitism, and disease and averages about 0.26 for males (0.08-0.23 for ages 5-10 years, 0.5-0.75 for 11-14 years) and 0.58 for females (103). Predation by Pacific cod during molting may account for much of the recent decline in the eastern Bering Sea (103), but diseases are also contributing factors to population declines throughout its range. Viral and microsporidian infections have occurred at significant levels in recent years (234,307). According to several authorities, viral diseases are the major cause of mortality in insects and are becoming recognized as causal agents in devastating epizootics in marine crustaceans (307). Among the infectious agents that invade red king crab are a lethal, putative viral disease of the antennal gland and bladder, a lethal microsporidan of the genus Thelohania that invades virtually all organ systems, and bacteria, acanthocephalans,

trematodes, leeches, and a rhizocephalan barnacle which reduces fertility (31,234,307).

Red king crab populations have also declined as a result of the fisheries. This species has been periodically overfished in some regions (182). In trawl fisheries, the red king crab is caught incidentally and discarded. Repeated capture and rehandling of females and sub-legal males during pot fisheries may affect survival and reproduction. This species could also be adversely affected by oil spills, especially if a spill occurred in or was transported (by wind or water currents) into nearshore nursery areas (103).

BLUE KING CRAB, Paralithodes platypus Brandt, 1850 (182)

(blue crab, king crab (156,288))

CLASSIFICATION

Phylum--Crustacea (29)

Class--Malacostraca (29,45)

Order--Decapoda (29,45)

Family--Lithodidae (45,302)

MANAGEMENT

Within Alaska, management policy is determined jointly by the State of Alaska and the North Pacific Fishery Management Council, and all crab fisheries are managed by the Alaska Board of Fisheries and the Alaska Department of Fish and Game (ADF&G). The Alaska Board of Fisheries (consisting of Governor-appointed members) considers regulatory changes proposed by the public or by ADF&G, receives testimony concerning proposals, and decides on regulatory changes. The Division of Commercial Fisheries of ADF&G is primarily responsible for king crab management, although in some areas of the state, the Division of Subsistence may also bear some of the responsibility. This Division is that part of ADF&G that is assigned to deal with harvests of fish and game for personal use as food rather than for recreational or commercial purposes. Subsistence utilization of fish and game has the highest priority in allocating resources, followed by commercial, and then recreational use.

VALUE

Commercial--This species is fished commercially with pots from the Siberian coast of the northwestern Bering Sea to southeast Alaska (229,301). In North American waters, the vast majority of catches (99%) comes from the eastern Bering Sea (8). Blue king crab fisheries in the eastern Bering Sea are relatively new (commenced in the 1970s); increased interest resulted from the decline of the red king crabs stocks in the early 1980s. In recent years (1981-83), harvests have annually averaged about 5,700 t and the peak catch of 1982 (nearly 6,000 t) represented 50% of the entire U.S. king crab harvest for that year (ex-vessel value to U.S. fishermen was over $30 million (10)). [Authors' update: Bering Sea catches have become substantially reduced; less than 1,300 t annually have been taken between 1984 and 1986 (110).] Harvests in the eastern Bering Sea are concentrated in areas off major offshore island groups such as Saint Matthew Island and the Pribilof Islands. Much smaller amounts are occasionally taken off Saint Lawrence Island (110). Annual catches in other Alaskan regions are quite small (less than 20 t, and taken incidentally in the red king crab fishery), and these catches are uncommon because they occur in coastal fjords that are often associated with glaciers, rather than in offshore regions (12,165). Some specific fishing areas outside the Bering Sea include Glacier Bay, northern Lynn Canal, lower Stephens Passage, Port Frederick, Freshwater Bay in southeast Alaska, and College Fjord in western Prince William Sound. Harvests are restricted by sex (males only), size, season, and quota. Most harvests in the Bering Sea (98.9%) occur from September to October, whereas catches from the remainder of Alaska occur primarily from October to December (9,10,82). As with other crab fisheries off North America, domestic fishermen are the only harvesters.

Recreational--Blue king crab is not an important recreational species.

Subsistence--It is caught by Eskimos through the ice in winter and spring near villages on Saint Lawrence Island and Little Diomede Island in the northern Bering sea (235). Small amounts are also occasionally taken by local residents on Nunivak Island (34).

Ecological--Blue king crab is the most important king crab and the major large crab species around offshore islands in the eastern and northern Bering Sea (31).

RANGE

Worldwide--Blue king crab is a boreal, Pacific species that ranges from the Sea of Japan (Cape Gamova, USSR) to the Chukchi Sea and southeast Alaska (8,31,182,345). In Asian waters, it is abundant off the Koryak Coast of Siberia (287).

Within Study Area--Its distribution is discontinuous. Blue king crab is found from the southern Chukchi Sea to the Pribilof Islands, and rarely in Kotzebue Sound, Norton Sound, or Bristol Bay (229,345). It also occurs in Herendeen Bay near Port Moller on the north coast of the Alaska Peninsula, in Olga Bay on Kodiak Island, western Prince William Sound, and in southeast Alaska from Icy Strait and northern Lynn Canal to Frederick Sound (8,31,298).

LIFE MODE

Eggs are brooded on the pleopods of the female. Zoeal larvae are pelagic and all other life stages are benthic (232,302).

HABITAT

Type--Larvae are neritic. Juveniles are found at depths less than 60 m (232). Most occur at 40-60 m in the eastern Bering Sea (110). Adults are found from 12 to 500 m, but are common at depths less than 200 m. Adults are most abundant in the Bering Sea and northward at depths less than 100 m (147,182,232,345).

Substrate--Juveniles are found in broken shell, gravel, cobble, and among rocks, and are notably absent from areas of sand and mud that occur between the crabs' preferred habitat (24). Adults occur on rock, sand, or mud bottoms (24,232).

Physical/Chemical--Larvae (and presumably other life history stages) are euhaline, occurring in waters of 30.0-32.0 ppt (134). Eggs, juveniles, and adults are found in water from -1 to 7°C. Larvae are found in water from 4.5 to 7.2°C (134,232). Adults prefer water from 0 to 4°C (288,345). Blue king crab populations outside the Bering Sea are usually associated with glaciers (229).

MIGRATIONS AND MOVEMENTS

Juveniles are nonmigratory (288). Adults generally show a seasonal bathymetric migration, but are nonmigratory off the Pribilof Islands (229). Along the Koryak Coast, they move to 300-400 m during the winter and from there to 50-100 m for summer spawning (182). Off Saint Matthew Island, adults move to depths less than 50 m during June and July (232). In Olga Bay, they do not occur at depths less than 30 m during October, but are found in shallow depths at other times (299).

POPULATION CHARACTERISTICS

Discrete populations occur in the northern Bering Sea, Saint Matthew Island, Pribilof Islands, Herendeen Bay, Olga Bay, Port Wells (Prince William Sound), Russell Fjord (Yakutat Bay), and in several enclosed (sill) bays and fjords in southeast Alaska (31,298).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (31).

Mating--Blue king crab mates from February to July at depths less than 65 m on rocky bottoms (31,232,238,302). Its mating behavior is similar to that of the red king crab. The male grabs the female by the chelipeds and holds her for up to 2 months, during which time she molts and is regrasped. She then presses her carapace onto the bottom and extrudes eggs while the male extrudes spermatophores onto her pleopods (182).

Fertilization--External (232).

Reproductive Potential--Fecundity increases with size and varies from 30,000 to 300,000 eggs (277,299). Males probably spawn each year, but females spawn every other year (some mate 2 years in succession) (302). Biannual female reproduction is likely due to the female's inability to produce a fully developed ovary in 1 year. The reason for this development problem is unclear (147).

Release of Young--Larvae are released from April to July at depths less than 65 m on rocky bottoms (24,31,232,238).

GROWTH AND DEVELOPMENT

Egg Size--1.0-1.3 by 0.9-1.1 mm (ellipsoidal) (302).

Embryonic Development--Indirect and external (182). Incubation time between 14 and 15 months (302). The larvae pass through four zoeal stages and one megalopal stage over a period of about 64 days (134).

Larval Size Range--3.2 mm CL and 4.9 mm TL at hatching and to 2.6 mm CL at the megalopal stage (134).

Juvenile Size Range--2.6 mm to 70-110 mm CL (134,232,301).

Age and Size of Adults--Males mature at 70-108 mm CL and females at 70-110 mm (50% at 80.6-93.7 mm) (232,301). Females reach a maximum of 170 mm and males grow to 190 mm (6.02 kg) (232). Blue king crab live up to 17 years (302).

FOOD AND FEEDING

Trophic Mode--Primarily carnivorous, but known to be omnivorous (predator and scavenger) (232).

Food Items--Zoeae probably feed on planktonic prey, and juveniles probably feed on benthic prey (similar to these stages of red king crab). Adults feed on sea urchins, polychaetes, bivalves, and brittle stars (232).

Feeding Behavior--Zoeae feed in the water column, whereas juveniles and adults feed on the bottom (232,298). Adults feed on hard and soft bottoms and excavate large pits in soft bottoms while searching for food (232,298). Chelae are used to crush sea urchin and mollusc shells (298). Juveniles are nocturnally active. Adults do not feed during spawning (182,298).

BIOLOGICAL INTERACTIONS

Predation--Blue king crab larvae are eaten by pink and chum salmon (134,182). Adults may be eaten by octopus, Pacific cod, Myoxocephalus sculpins, and Pacific halibut (182,293). Juveniles avoid some predation through cryptic coloring of their exoskeletons. Adults probably defend themselves in a manner similar to red king crab. Juvenile blue king crab spines are shorter than those of juvenile red king crab (298).

Competition--Red king crab is a potential competitor. The two species are seldom found together, but when they are, red king crab is faster and more aggressive (298).

Symbiotic Relationships--Blue king crab is infected by at least one virus, Chlamydia rickettsia; a microsporidan parasite, Thelohania sp.; and trematodes (232,307). It is also parasitized by a rhizocephalan barnacle, Briarosaccus callosus (165,302). Unlike golden king crab, this species can tolerate multiple parasitisms. Four rhizocephalan externae may be found on an individual (283).

Community Associations and Interactions--Blue king crab is a member of a middle shelf community in the Bering Sea that includes butterfly sculpin, snailfishes (Liparis), and eelpouts (Lycodes) (293). They also occur in the same area as the northern Tanner or snow crab (Chionoecetes opilio) (298).

FACTORS AFFECTING POPULATIONS

Rhizocephalan parasites decrease oocyte development in females (302) and decrease somatic growth in both sexes (283). Growth inhibition and castration by barnacle parasitism could severely limit recruitment, especially since many populations occur in isolated locales. Barnacle parasitism has not been observed in specimens from the eastern Bering Sea (307), but very high parasitism rates have been reported in southeast Alaska (283). A reason for

incidence of parasitism in southeast Alaska may be environmentally related. Parasitism may be associated with the silt-mud bottom sediment of glacial runoff. Turbid water may impede gill cleaning efficiency, thus favoring barnacle attachment since host infection apparently occurs in the gill region (283). Commercial fishing removes 40-60% of the adult males over 135 mm and may cause mortality in others.

NORTHERN PINK SHRIMP, Pandalus borealis Kroyer, 1838 (135)

(pink shrimp, deep-sea shrimp, prawn, deepwater great northern prawn (86,135); commonly called pink shrimp by fishermen in Alaska and British Columbia (55))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Pandalidae (135,29,45,135)

MANAGEMENT

Since most catches occur within 3 miles of the coast, northern pink shrimp in Alaska is managed through its Board of Fisheries and Game with recommendations from the Alaska Department of Fish and Game. The management strategy by Alaska considers populations within numerous geographic areas (as small as individual bays) as separate nonmixing stocks. Harvests for each area are regulated separately (104). Gear restrictions and seasonal closures are used to restrict harvests (163). The North Pacific Fishery Management Council has identified northern pink shrimp as a prohibited species (i.e., all groundfish fisheries in the eastern Bering Sea and Gulf of Alaska must not retain any catch of this species) (213). The Canada Department of Fisheries and Oceans monitors harvests in British Columbia waters.

VALUE

Commercial--Pandalid shrimp is the dominant shrimp group harvested in waters off the west coast of North America. Northern pink shrimp and the ocean pink shrimp are the most important Pandalid forms in the northeast Pacific:

northern pink shrimp in Alaskan waters (85% of catch) and ocean pink shrimp in waters south of Alaska.

Northern pink shrimp is fished commercially in both the North Pacific and North Atlantic Oceans. Its small size (130-250 individuals per kg) and occurrence in dense concentrations over smooth ocean bottoms makes it ideal for harvest by otter trawls. In the North Pacific, it has been harvested from waters off the coast of Korea and from British Columbia to the northern Bering Sea (55,86,135). Its regional commercial importance has widely fluctuated in conjunction with its abundance. During the early 1960s, 10,000 to 30,000 t harvests were annually taken by foreign fleets in the Bering Sea (from the Pribilof Islands to the Gulf of Anadyr). Following a precipitous decline in abundance due mostly to overfishing, interest switched to the Gulf of Alaska stocks, and domestic fleets became the major harvester of this resource. Shrimp harvests in the Gulf of Alaska rapidly increased through the mid-1970s until nearly 60,000 t were taken in 1976. This was one-third of the worldwide Pandalid shrimp harvest for that year (ex-vessel value was $11.5 million; record in 1977 was $20.0 million). Continuously expanding harvests and environmental changes (see FACTORS INFLUENCING POPULATIONS) in the 1970s resulted in a decimation of the resource in the Gulf of Alaska, and by 1983 the shrimp catch for all Alaska had been reduced to less than 3,000 t (1981-83 average: 7,350 t and about $6 million) (12). [Authors' update: low catches continue; only about 1,700 t were taken statewide in 1985 (this total does not include small amounts taken with pots) (14).]

Gulf of Alaska harvests during the high catch years focused on coastal areas at depths of 50-100 m off the southeast coast of Kodiak Island and in several bays along the south coast of the Alaska Peninsula (141). Current grounds are not as extensive as in earlier years but are scattered over a wide area from Adak Strait in the Aleutians to Dixon Entrance (Alaska-British

Columbia border). Recent Alaska harvest areas in order of importance (and percent of 1981-83 catch) include: the east side of the Kodiak Island region from Alitak Bay to Afognak Island (45% of entire catch with over half of that from Alitak Bay alone), Kachemak Bay in southern Cook Inlet (especially west and south of Homer Spit) (20%), Alaska Peninsula bays along Shelikof Strait from Chignik to Cape Nukshak (17%), southeast Alaska (mostly in the Stikine River Delta area) (8%), the eastern Aleutian Islands (mainly Makushin Bay on Unalaska Island) (6%), Prince William Sound (especially in Knight Island Passage) (2%), the south coast of the Kenai Peninsula from Nuka Bay to Aialik Bay (2%), and Yakutat Bay (less than 1%) (12). Additionally, this species is harvested in British Columbia waters in very minor amounts. British Columbia harvest areas include: Chatham Sound (near Prince Rupert), Howe Sound, and around the Gulf Islands in the southern part of the Strait of Georgia (115). There has been no shrimp harvest by foreign fleets since passage of the MFCMA in 1976. Shrimp fishing in British Columbia waters is undertaken only by Canadians.

Fishing seasons vary by region. For example, for Kodiak and areas to the west, the season starts in June, with most catches occurring from June to October; for Cook Inlet to Prince William Sound, the season starts in July and extends mostly from July to February; and for southeast Alaska, the season opens in May and lasts mostly from May to June. Seasonal closures are usually associated with protection of the resource during sensitive life history stages such as during larval release and molting. Commercial fishing is prohibited in Glacier Bay, Alaska, by the National Park Service; shrimp in that area are considered an important food item for whales (163).

Some northern pink shrimp is sold fresh and whole, but because of their small size, most are peeled by machine and marketed frozen or canned.

Recreational--This species has no recreational value because of its small size and depth distribution.

Ecological--It is one of the most abundant shrimps in the North Pacific and Atlantic. It is an important component of the coastal food web off Alaska (30,91,284).

RANGE

Worldwide--The species is Arctic-amphiboreal and occurs in the North Pacific and Atlantic Oceans. In the North Pacific it is found from South Korea to the north coast of Alaska (Point Barrow) and south into southern California (San Diego) (55,340). In the North Atlantic it occurs from the Massachusetts coast north to western Greenland and from the Barents and Kara Seas south to the coast of the United Kingdom (284,340).

Within Study Area--Westernmost Aleutian Islands and the Gulf of Anadyr in the Bering Sea to San Diego, California; not abundant south of British Columbia and only occasionally encountered south of the Columbia River (284).

LIFE MODE

Eggs are brooded on the pleopods of the female. Larvae are pelagic. Juveniles and adults are benthopelagic (55,284).

HABITAT

Type--Larvae are primarily neritic and occur in the water column from the surface to 100 m (343). Early stages occur in shallow areas with bottom depths less than 50 m (284,340). Juveniles are sublittoral and first occur on the bottom at depths of 46 to 64 m. They move into deeper water by winter (284,340). Adults are estuarine-sublittoral-bathyal and are found at depths

of 9 to 1,450 m (284,340), although in the North Pacific most are found at depths less than 250 m, and most are encountered at 50 to 200 m.

Substrate--Juveniles and adults are found on soft bottoms, usually of clay, mud, or sandy silt, but occasionally they can be found on sand, gravel, or rocky substrate when not in the water column (135,284,340).

Physical/Chemical--Northern pink shrimp are found in polyhaline-euhaline waters of 23.4 to 35.7 ppt and occur at water temperatures of -1.6 to 16°C, but occur mostly at 0 to 5°C (284).

MIGRATIONS AND MOVEMENTS

This species undertakes a series of bathymetric migrations that are related to maturity and reproduction. Juveniles move from shallow to deep water as they mature as males. Males mate with females and transform into females in deep water. Ovigerous females migrate from deep water to shallow water to release larvae and then return to deep water to mate again and repeat the cycle. Adults can move up to 40 km during these migrations (284). Northern pink shrimp also make diel vertical migrations that are associated with nocturnal feeding (32). The pelagic larvae ascend from daytime midwater depths to nearer the surface at night (284,343). Juveniles and adults remain on or near bottom during the day and move from the surface (or thermocline) to the bottom at night (284). Juveniles migrate more frequently than adults. Ovigerous females do not participate in the vertical migrations (32,284).

POPULATION CHARACTERISTICS

North Pacific and North Atlantic populations are discrete (at one time considered subspecies). Morphological and genetic studies of samples from Alaska suggest that northern pink shrimp found in the eastern Bering Sea form a separate population from shrimp in the Gulf of Alaska. Stocks along the

western part of the Alaska Peninsula, around Kodiak Island, and in Yakutat Bay in the eastern Gulf of Alaska should be treated as individual breeding units for purposes of management (105).

REPRODUCTION

Mode--Sexual, primarily protandric hermaphrodites, although in British Columbia and the North Sea, 30-50% initially mature as and remain primary females; oviparous (340).

Mating--Mating occurs at depths from 113 to 274 m. At the time of mating, the female molts at night and oviposition occurs within 36 hours. The male touches the female with antennae, swims in circles, and then palpates the female all over with its chelae. Male and female then lie side by side on the bottom with the ventral portions of their bodies together. The male deposits spermatozoa in a loose mass on the pleopods of the female and oviposition occurs. Mating is from July to February, varying with temperature (mating occurs earlier in colder regions) (284). Timing by region varies as follows: Spitzbergen (Barents Sea), July through October; Gulf of Alaska, August through October; British Columbia, Norway, and Japan, October through February (220,284,340).

Fertilization--External (284).

Reproductive Potential--Fecundity increases with body size and ranges from about 300 to 4,900 eggs per female (carapace lengths of 21-31 mm) (284). In the North Pacific, fecundity is greater in Alaska than in British Columbia (55). From laboratory experiments on Gulf of Alaska shrimp, it was found that, in the natural environment, total population fecundity will vary with temperature by as much as 20% (220). Each individual spawns once a year (284). Primary females spawn twice during their lives, whereas protandric hermaphrodites spawn once as males and once or twice as females (55,284).

Spawning--Water temperature is thought to be the factor controlling the spawning and hatching throughout the geographic range of the northern pink shrimp (220). Larval release occurs from March to June (mostly March-April) in the northeast Pacific, from January to April in the northwest Atlantic, and from April to July in the northeast Atlantic (55,284,343). Hatching occurs from 9 to 179 m (284).

GROWTH AND DEVELOPMENT

Egg size--Oval, 2.0 by 1.0 mm (284)

Embryonic development--Indirect and external. At fertilization the eggs are glued to the pleopods of the female and brooded until hatching. Incubation time ranges from 4 to 11 months depending upon latitude and temperature (55,284). Off British Columbia and the United Kingdom, incubation lasts from 4 to 4.5 months; 7 to 8 months in the Bering Sea; and 10 to 11 months off Spitzbergen (32,5,284). Laboratory experiments on Gulf of Alaska shrimp indicate that incubation averages 3.5 months at 9°C, 3.8 months at 6°C, and 6.1 months at 3°C (220). Larvae develop through seven stages. The duration of the larval period ranges from 1.5 months at 10°C to 4 months at 4°C. (284).

Larval size range--Larvae hatch at 5.0 to 6.5 mm and metamorphose at 19.0 to 20.5 mm (32,284).

Juvenile size range--19-20.5 mm to 87 mm TL (30,284).

Age and size of adults--Growth and ages at maturation, sex reversal, and death vary with latitude and temperature. In general, growth is slower and ages at which significant changes in life cycles occur are later at higher latitudes (55,340). Males mature from 1.5 to 3.5 years with a carapace length of 14 to 16 mm, total length of 87 mm, and weight of 3 g. Primary females mature at 1.5 years with a carapace length of 23 mm and a weight of 3 g (284,55). After mating, males transform into females through several molts. Secondary females

mature at 2.2 to 6 years with a carapace length of 21 to 27 mm, a total length up to 119 mm, and a weight of 6 g (55,284,340). Maximum age is 6 years for males and 11.8 years for females (284,340). At low latitudes, maximum age may be less than 4 years (55,340). Males reach a maximum carapace length of 20 mm and 121 mm TL, and females reach 37 mm CL and 182 mm TL (55,284).

FOOD AND FEEDING

Trophic Mode--Omnivore.

Food Items--Larvae feed on diatoms, copepods, other planktonic crustaceans, and polychaetes (45,284). Adults are opportunistic foragers that feed primarily on benthic and planktonic crustaceans, polychaetes, and foraminiferans (32,55,91,199,284,340).

Feeding behavior--Adults feed primarily on the bottom, but also in the water column. Juveniles may feed more in the water column than adults (32,284). Benthic feeding occurs during the day and pelagic feeding at night (32,102,284). Females stop feeding during premolt periods or near spawning. The northern pink shrimp finely grinds its food by passing it through a gastric mill containing sand or small stones (284).

BIOLOGICAL INTERACTIONS

Predators--Northern pink shrimp are preyed upon by a large number of organisms, primarily vertebrates (although this species is also eaten by octopus and it may eat the eggs of its own species). Vertebrate predators include Atlantic hagfish, spiny dogfish, salmon, gadoids (Pacific cod, Atlantic cod, walleye pollock, silver hake, Pacific hake (= Pacific whiting)), rockfishes, sculpins, eelpouts, flatfishes (arrowtooth flounder, rex sole, flathead sole, Pacific halibut, yellowfin sole, Greenland halibut), whales seabirds, and harbor seals (17,30,32,91,284,340).

Competition--Northern pink shrimp competes with Greenland shrimp (Eualus macilenta) and Aesop shrimp (Pandalus montaqui) in the North Atlantic (284) and probably with other pandalid shrimps in the North Pacific.

Social interactions--Northern pink shrimp form schools and aggregate on the bottom in patches of similar-sized individuals (284).

Community Associations and Interactions--In the Bering Sea, northern pink shrimp are associated with Tanner crabs, skates, Pacific cod, walleye pollock, flathead sole, rock sole, and Greenland halibut (293).

FACTORS INFLUENCING POPULATIONS

Fecundity in northern pink shrimp decreases with increasing population size. In addition, eggs are lost due to accidental detachment during movements of the female, killed by a flagellated protozoan, or eaten by other northern pink shrimp (284). Larvae have a critical period of about 30 hours at 4 to 5°C when they must obtain food after hatching before they starve. At high temperatures, larval mortality is highest at early stages. Larval mortality increases with decreasing salinity at low temperatures (284). Low temperatures can cause mass mortalities, slower growth, earlier mating in a season, delayed sex reversal, longer incubation times, and later hatching in a season (340). Mass mortalities occur at -1.6°C and high temperatures are deleterious in the south. Adults are infested by microsporidia, nematodes, rhizocephalan barnacles, and bopyrid isopods, and they have a black spot syndrome on the gills that peaks during fall and winter (284). Bopyrid infestation may inhibit sex reversal and may be fatal to males (about 3%) (32,284). Natural mortality is 0.2-0.5 (284).

Decreases in abundance have been attributed to overfishing in the North Sea during the 1950s and in the Bering Sea in the 1960s (27,284). The collapse of the northern shrimp fishery in the Gulf of Maine in the mid-1950s

was attributed to high winter water temperatures that caused poor egg production (23). High winter water temperatures and overfishing are considered joint probable causes for the dramatic decline of Gulf of Alaska stocks in the late 1970s (99). Continued low abundance in the Gulf of Alaska is partially attributed to predation by strong year classes of Pacific cod (17).

OCEAN PINK SHRIMP, Pandalus jordani Rathbun, 1902 (135)

(Ocean shrimp, pink shrimp, smooth pink shrimp (28))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Pandalidae (2,45,135)

MANAGEMENT

Although this species is harvested up to 46 km offshore, it is managed by state fisheries agencies in Washington, Oregon, and California. The Canada Department of Fisheries and Oceans monitors harvests in British Columbia waters.

VALUE

Commercial--This species, in combination with a similar, more northern form, the northern pink shrimp (P. borealis), comprises the bulk of shrimp harvests along the entire Pacific coast of the United States and Canada (28). It is fished commercially with trawls from Queen Charlotte Sound, British Columbia to central California (55,174,243), but mostly from Washington to northern California (243). Ocean pink shrimp fisheries occur from 4 to 46 km offshore and at depths of 60 to 300 m, primarily 100-200 m (76,77,174,243). Fisheries for this species started in the 1950s and since that time have become very important. During 1974-83, annual harvests averaged about 20,500 t (245) with a peak harvest in 1978 of nearly 38,000 t. This record catch had a value to fishermen of about $18 million (10,209). Recent harvests (1981-83) are down substantially from the earlier peak and annually average about 12,500 t with

an ex-vessel value of $11-14 million (204,207-209). [Authors' note: post-1983 harvests increased substantially, at least through 1987, but are still below peak amount; value of 1987 catch may have approached a record $48 million.]

Major fishing areas are discontinuous, generally the same from year to year and include locations such as offshore of Nootka and Clayoquot Sounds on the west coast of Vancouver Island, British Columbia (68,69,70,115); off the Washington coast from Cape Alava to Cape Shoalwater (243); off the Oregon coast from Astoria Canyon to Yaquina Head, and from Cape Perpetua to Cape Blanco (243); from Brookings, Oregon, to Trinidad Head in northern California and off San Luis Obispo Bay on the south-central California coast (243,349). Over half of recent annual harvests occur from April to June with 90% taken from April to September (245).

Ocean pink shrimp are small (average size in catches range from 56 to 200 individuals per pound (275,349)) and most are cooked, machine peeled, and frozen in 5-pound cans or cooked in vacuum packed cans (102,135,243). The fisheries are entirely domestic with over 95% of harvests taken in U.S. waters. Either sex is harvested, but the fisheries focus on females because of their size (see Age and Size of Adults). There is usually a closure of the fishery during November-March to protect the population during most of its reproductive period.

Recreational--This species has almost no recreational value because of its small size and depth distribution.

Ecological--Ocean pink shrimp can be a major prey item of many fishes, especially of Pacific hake (= Pacific whiting), depending on seasonal and local abundance (77,109).

RANGE

Worldwide--This is a boreal, eastern Pacific species with a range confined to the study area.

Within Study Area--It is found from Unalaska Island, Alaska, to San Diego, California (55,135), and is abundant from southern Vancouver Island, British Columbia (Cape Beale), to northern California (77).

LIFE MODE

Eggs are brooded on the pleopods of the female. The larvae are pelagic. Juveniles and adults are benthopelagic (77).

HABITAT

Type--Larvae are neritic and are found from the surface to 150 m (274). Juveniles are found on the bottom in the shallow portion of the depth range of the adult to at least 160 m, but occur in the water column to the surface at night (77,274). Adults are found on the bottom in 36 to 357 m of water (mostly 50-250 m) and can migrate to the surface at night (55,102).

Substrate--Juveniles and adults are found primarily on green mud or bottoms of mud and sand when not in the water column (77).

Physical/Chemical--Ocean pink shrimp occurs in polyhaline-euhaline waters of 28.7 to 34.6 ppt (77). Eggs, juveniles, and adults are found in water temperatures of 5.6 of 12.2°C (77,273,280).

MIGRATIONS AND MOVEMENTS

Seasonal--Ocean pink shrimp undertakes a seasonal bathymetric migration. Beginning in the fall, females move to greater depths to spawn, usually about 18-37 m deeper than normal (77,174). Off Morro Bay, females move from depths of 186 m to 256 m during this time. Movement in the spring occurs after eggs

have hatched and is influenced by winds, tides, and food availability. Males are found at 75 to 128 m from January to June, but join females in deeper water from July to December (77). Off the Washington-California coast, there is an apparent southward drift of larvae and a northward movement of juveniles and adults (34).

Diel--Diel vertical migrations begin in stage VIII larvae and continue through the juvenile and adult phases, although most vertical migrators are mature males (249,274). Older larvae stay in midwater at depths of 150 m during the day but rise to the surface at night (274). Juveniles and adults are found throughout the water column at night except during May and June (249,274). On bright sunny days they remain on the bottom but on overcast days they may rise up to 22 m above the bottom (55,174).

POPULATION CHARACTERISTICS

Ocean pink shrimp are found in discontinuous beds which occur in the same area from year to year (77). Although little intermixing between beds occurs among adults, much intermixing probably occurs in the larval phase. As a result there is no indication of genetically distinct subpopulations (102). Despite no clear genetic separation, recent studies have suggested the presence of three relatively separate "stock units" based on growth differences: south of Cape Mendocino, California; between Cape Mendocino and Astoria Canyon (mouth of the Columbia River); and north from there (349).

REPRODUCTION

Mode--Sexual, protandric hermaphrodites with some primary females, oviparous. In some years near the southern edge of its range, primary females may comprise up to 68% of the population (76,77).

Mating--Mating occurs from September to December in deep water (102). Mating is probably promiscuous, and the larger females mate earliest in the season (77).

Fertilization--External (77).

Reproductive Potential--Fecundity varies with region and increases with age and size (77). Numbers of eggs per female range from 800 to 3,900 (77,102). Spawning occurs once a year, and ocean pink shrimp mate once as males and once or twice as females. Primary females may mate one to three times during their lives (77).

Release of Young--Larvae are released from February to May (77,273). The largest females are the earliest to release their young (77). Larvae are probably released at depths of 200 m as ovigerous females are found at that depth (273). Larvae are not released inshore (273).

GROWTH AND DEVELOPMENT

Egg Size--Elliptical, 0.70 to 2.00 mm in length, 0.55 to 0.59 mm in width; the size varies with the time of incubation (77).

Embryonic Development--Indirect and external (77). Incubation lasts 4.5-5.0 months (55,77). Larvae pass through 13 stages of development (273). The larval period generally lasts from 79 to 85 days and occurs sometime from February to August (55,273).

Larval Size Range--5.0-17.0 mm (77).

Juvenile Size Range--4.5 mm to 15-18 mm CL (77). Juveniles first appear between June and August of their initial year.

Age and Size of Adults--Males and primary females mature at 1.5 years. Males are 15-18 mm CL and weigh 3.7-4.0 g at maturity; primary females are 17-20 mm CL and weigh 3.7-3.9 g (55,77). Males change sex at 17.9-21 mm CL (about 125 mm TL, maximum) and at 4.0-5.7 g. Sex reversal occurs at 2 years

of age (55,77). Secondary females mature at 2.5 years with a carapace length of 20.2-21.6 mm and a weight of 5.8-6.8 g (77). Maximum age is 5 years in the north and 3 years in the south (174). Maximum size is 30 mm CL and 10 g (28,55,135).

FOOD AND FEEDING

Trophic Mode--Carnivore, detritivore (249)

Food Items--Ocean pink shrimp feed on euphausiids and copepods in the water column at night and on polychaetes, amphipods, diatoms, sponges, mud, and detritus while on the bottom during the day (77,102,249).

Feeding Behavior--They feed in the water column at night and on the bottom during day. Food is captured with the second pair of pereiopods and brought to the mouthparts (77).

BIOLOGICAL INTERACTIONS

Predation--Ocean pink shrimp is eaten by spiny dogfish, skates, Pacific cod, Pacific hake (= Pacific whiting), redbanded rockfish, greenstriped rockfish, stripetail rockfish, sablefish, lingcod, arrowtooth flounder, and petrale sole (55,77,109). Its schooling behavior, long rostrum, and backward dart when surprised are all protective adaptations against predation (77).

Competition--Ocean pink shrimp is replaced by northern pink shrimp from British Columbia to Alaska. Besides competing with related shrimps, Ocean pink shrimp may compete with seastars, urchins, and early life stages of many fishes (e.g., spiny dogfish, Pacific hake (= Pacific whiting), sablefish, arrowtooth flounder, rex sole, and slender sole) (77).

Community Associations and Interactions--It is associated with Pacific hake (= Pacific whiting), Pacific sanddab, rex sole, slender sole, and Dover sole (77,280).

FACTORS INFLUENCING POPULATIONS

Larval survival is greater during years of moderate upwelling (76). Upwelling maintains cool temperatures for optimal development, stimulates food production, and transports later-stage larvae to settling grounds (273). Adults are parasitized by microsporidians, rhizocephalan barnacles, and bopyrid isopods. Branchial infestation by Bopyroides hippolytes retards growth, accelerates sex change, and results in 0.3 to 0.6% mortality (off Canada) (55). Natural mortality is greatest at egg-laying and is about 46% in the first winter, 76% in the second, and 43% in the third (77,102). Total mortality is about 61% (48-70%) and is largely due to predation and fishing (77). Ocean pink shrimp usually are not vulnerable to fishing until the second year (109); however, in the latter months of the 1985-86 fishing season in California, more than half of some landings were young-of-the-year shrimp (76).

COONSTRIPE SHRIMP, Pandalus hypsinotus Brandt, 1851 (135)

(helmet shrimp, humpback shrimp, king shrimp (55))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Pandalidae (29,45,135)

MANAGEMENT

This species is managed and harvests are monitored by each state (or province) in which harvests occur. These include Alaska, Washington, and British Columbia. The North Pacific Fishery Management Council has identified it as a "prohibited species" in their Fishery Management Plan for groundfish (i.e., retaining by-catches of this species during groundfish fishing is forbidden) (215).

VALUE

Commercial--This species is of minor commercial importance in North American waters and is usually captured incidentally during fisheries for other shrimps, especially the spot shrimp pot fishery. Commercial harvests off North America occur from Kodiak Island, Alaska, to northern Puget Sound, Washington, but harvests mostly come from Alaskan waters in Kachemak Bay (a directed pot fishery), northwest Prince William Sound, and Lituya Bay (12). Other harvest areas include: numerous bays throughout southeast Alaska; Stuart Channel, Burrard Inlet, and Knight and Kingcome Inlets in British Columbia; and Hood Canal, Port Susan, and areas in the San Juan Islands in Washington (12,55,163,331). Since this is usually an incidentally caught species,

harvest amounts are not always reported. Of the 176 t landed from 1981 to 1983 in U.S. waters, 90% were taken in Alaska and over 75% solely from Kachemak Bay (12,331). Fishing seasons vary by region. Multiple seasons may occur within a region, and most of a seasonal quota is taken not long after the opening date (161).

Recreational--This is not an important recreational species except in Kachemak Bay and possibly Prince William Sound. Sportfishing is open year-round but weather limits activity; peak harvests occur in summer (161).

Ecological--Coonstripe shrimp is probably an important prey of fish in areas where it is abundant.

RANGE

Worldwide--This is a boreal, Pacific species that is found from Korea Strait and Puget Sound north to the northern Bering Sea (55).

Within Study Area--Adak Island in the central Aleutian Islands to Hood Canal in Puget Sound; also, an isolated population occurs in Norton Sound (344).

LIFE MODE

The eggs are brooded on the pleopods of the female and the larvae are pelagic (172). Juveniles and adults are benthopelagic (30).

HABITAT

Type--Larvae are neritic, occurring from the surface to 20 m over bottom depths 5-50 m. Stage I larvae occur near the habitat of the adult, and later stages occur inshore (171,172). Juveniles are sublittoral and occur on the middle shelf at 32-82 m (55,172). Adults are sublittoral-bathyal and range from 5 to 460 m (55). Over 95% of the occurrences of this species during NMFS

resource assessment surveys have been at depths less than 150 m (344). Small individuals occur in the water column at night (30).

Substrate--Juveniles may occur in terrestrial plant debris on the bottom (172). Adults prefer sand or gravel bottoms, although they occasionally occur on mud or rocky substrates (28). Both juveniles and adults can occur in the water column.

Physical/Chemical--Coonstripe shrimp occur in polyhaline-euhaline waters of 25.9-34.0 ppt (55,172). Eggs, juveniles, and adults are found in water of 6.3-11.8°C (55,172). Larvae occur at 6.0-18.0°C with 9.0-12.0°C being optimal for feeding (121,172).

MIGRATIONS AND MOVEMENTS

Seasonal--Undescribed.

Diel--Juveniles migrate into the water column at night (30).

POPULATION CHARACTERISTICS

Undescribed.

REPRODUCTION

Mode--Sexual, protandric hermaphrodite with some primary females, oviparous (55,172).

Mating--Generally occurs in September to early December, but off the Pacific Coast of Japan it occurs as early as June or July (55,172).

Fertilization--External.

Reproductive Potential--Fecundity increases with size and ranges from 1,000 to 9,000 eggs per female (carapace lengths of 30-50 mm, respectively) (172). Each individual mates once a year (172). Hermaphroditic shrimp mate once or

twice as males and once as females. Primary females mate twice as females (55,172).

Release of Young--Eggs hatch into larvae from February to March at depths of 30 m (55,121).

GROWTH AND DEVELOPMENT

Egg Size--Elliptical, 1.8 mm long (172).

Embryonic development--Indirect and external (55). Incubation time ranges from 6 to 11 months (172). Larvae pass through nine stages during development (121). The larval period usually occurs during March-June and varies in length with temperature, ranging from 21 days at 18°C to 53 days at 7°C (172).

Larval Size Range--5.5-13.8 mm (121).

Juvenile Size Range--13.8-102 mm TL (55,121).

Age and Size of Adults--Males and primary females mature at 1.5 years with a length of 24.1 mm (carapace) and 102 mm (total) and a weight of 10.3 g (55). Males undergo sex reversal at 2-3 years (beginning in March-May) over a series of 4-5 molts. Secondary females appear at 2.5-3.5 years at 29.1-41.0 mm CL (151-173 mm TL). Maximum age is less than 4 years and maximum length is 51 mm (carapace) and 216 mm (total) (55,172).

FOOD AND FEEDING

Trophic Mode--Carnivore (172).

Food Items--Larvae feed on planktonic crustaceans; stage I larvae eat up to 31-38 nauplii per day (172). Adults feed on mysids and amphipods during spring and summer and annelids during fall and winter. Small bivalves, gastropods, ophiuroids, and fish parts are taken throughout the year. About 50% of the males and 70% of the females have empty stomachs (172). Feeding

behavior is probably similar to that of other pandalid shrimps. Larvae feed more actively at night (172).

BIOLOGICAL INTERACTIONS

Predation--Coonstripe shrimp are eaten by sand sole (55).

Competition--Not described.

Social Interactions--Not described.

Community Associations and Interactions--Not described.

FACTORS INFLUENCING POPULATIONS

Larval survival is greater during years of moderate upwelling (32). Upwelling maintains cool temperatures for optimal development, stimulates food production and transports later-stage larvae to settling grounds (161). Adults are parasitized by microsporidians, rhizocephalan barnacles, and bopyrid isopods. Branchial infestation by Bopyroides hippolytes retards growth, accelerates sex change, and results in 0.3 to 0.6% mortality (off Canada) (171). Natural mortality is greatest at egg-laying and is about 46% in the first winter, 76% in the second, and 43% in the third (12,331). Total mortality is about 61% (48-70%) and is largely due to predation and fishing (12). The Japanese stock decreased due to overfishing in the mid-1950s (172).

SPOT SHRIMP, Pandalus platyceros Brandt, 1851 (135)

(prawn, spot, spot prawn (55))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Pandalidae (29,45)

MANAGEMENT

Since most catches occur within 3 miles of the coast, this species is managed and harvests are regulated by each state (and province) in which harvests occur. These include Alaska, Washington, California, and the Province of British Columbia (245,281,350).

VALUE

Commercial--This species is fished commercially along the Asian coast off Korea and along the North American coast from the northwestern Gulf of Alaska to south-central California (12,28,54). Spot shrimp is usually fished on the bottom with pots and occasionally with trawls (55,54). It is an important commercial species because of its large size (individuals weighing up to 0.4 lbs have been taken). It is the second or third most important shrimp species in Alaska and British Columbia, but only makes up about 5% of annual shrimp harvests in these regions combined. [Authors' note: although shrimp harvests in British Columbia are relatively small, 40% of the total harvest is composed of spot shrimp.] In other areas it is less abundant (8,10,28,58,60, 63,135,245). Catches off the west coast of North America in recent years (1981-83) have averaged about 650 t annually, with about 50% coming from

Canadian waters, 33% from Alaska, and most of the remainder (15%) from central and southern California.

Spot shrimp are found in rocky habitat and are taken primarily in fjords and coastal channels from Alaska to Washington and in rocky canyons off California. Major fishing areas include: Prince William Sound (especially Montague Strait, Port Wells, and Knight Passage), southeast Alaska (primarily from Ernest Sound to Dixon Entrance and Cordova Bay; many other bays also), British Columbia (along the mainland and west coast of Vancouver Island), Puget Sound (Hood Canal), and off the California coast from Monterey to Santa Barbara (12,58,60,63,68-70,328,331). These shrimp are fished at 91-110 m in southeast Alaska, 73-165 m in British Columbia and Puget Sound, and 152-274 m off California (54,102).

Harvests occur year-round in some areas and vary seasonally in others. Alaska recently developed harvest restrictions in some areas to protect stocks during egg-carrying and larval release periods (15,164). One result of these restrictions is a primarily fall-winter fishery in southeast Alaska (164). Trawling in Santa Barbara Channel in California is restricted to February-October (316).

This species has an excellent flavor and is usually marketed as fresh or fresh-frozen, uncooked tails.

Recreational--Recreational harvests of spot shrimp generally occur near coastal communities when areas of abundance are located there. Sport harvests occur from Kachemak Bay (lower Cook Inlet), Alaska, to Hood Canal, Washington. An example of its recreational popularity is that over 7,000 Hood Canal spot shrimp sportfishing licenses were sold in 1986 (138). [Authors' note: there are no sport harvests in Alaska; noncommercial, resident harvests are called "subsistence," and nonresident harvests with a sportfishing license are called "personal use." Both are essentially recreational in nature (163).]

Ecological--Spot shrimp are a major detritivore and prey species for fishes on rocky bottoms.

RANGE

Worldwide--This is a boreal, Pacific species that occurs off Asia in the Sea of Japan and off North America from Alaska to California (55).

Within Study Area--It is found from Unalaska Island, Alaska, south to San Diego, California, and is locally abundant in areas from Kodiak Island, Alaska, to Santa Catalina Island, California (12,86,102). One source indicates that this species is also found in Bering Strait, north of the Bering Sea (#135).

LIFE MODE

Eggs are brooded on the pleopods of the female. The larvae are pelagic and the adults are benthopelagic (55,54).

HABITAT

Type--Eggs are brooded on the pleopods of the female at depths of 70-216 m (55,102). Larvae are neritic. Spot shrimp in early stages of development are found in the lower half of the water column over waters 70-216 m deep; shrimp in later stages are found in 4-6 m of water (54). Juveniles are found from 0-55 m during their first year and then move deeper to adult grounds. They also occur in midwater (54,55). Adults are found from the intertidal zone to 532 m, but generally occur at depths greater than 50 m during the day and in shallow areas only at night (55,267). Adults may migrate into the middle and upper layers of the water column at night (102). Nearly all occurrences of this species have been at depths of 20 to 200 m during NMFS resource

assessment surveys, and more than 90% of all occurrences at depths of 50-100 m (344).

Substrate--Juveniles are generally found among kelp; green, red, and brown algae; and sea grasses on rocky bottoms (55). Adults are generally found in rocky areas with boulders and steep rock faces, but occasionally occur on green mud near rocks (28,55,102).

Physical/Chemical--Spot shrimp are found in polyhaline-euhaline waters of 26.4-34.0 ppt at temperatures of 7-22°C and dissolved oxygen of 5.0-11.0 ppm (55,260,267).

MIGRATIONS AND MOVEMENTS

Seasonal--Bathymetric movements by adults in southeast Alaska are apparently shallower in spring and deeper in fall (based on personal knowledge by R. Wolotira, aquired during exploratory fishing surveys of Ernest Sound during 1966 and 1967).

Diel--Spot shrimp make diel migrations and are more abundant at bottom depths of 18-49 m at night and 51-73 m during the day (73). It is assumed that this may include movement into middle and upper levels of the water column (102).

POPULATION CHARACTERISTICS

Undescribed.

REPRODUCTION

Mode--Sexual, protandric hermaphrodites (with no primary females), oviparous (55,73).

Mating--Mating occurs from September to December at depths of 70-216 m (55,73,102). Laboratory observations indicate that mating commences shortly after the female molts. The recently molted female, unable to move because of

her new unhardened exoskeleton, is approached by the male, and he palpitates her immobile body with his appendages (palpitation by 3rd pair of maxillipeds and 1st and 2nd pereiopods was observed). The passive female is then positioned ventral surface upward by the male, mounted, and grasped. The male then contracts his abdominal musculature, beats his pleopods violently and deposits spermatophores onto the female. The copulation process is completed within a few minutes, and if other males are present, subsequent mating(s) may commence within about 20 minutes of the initial mating. Body alignment during copulation varies from both sexes facing the same direction to the opposite direction; abdominal areas are always adjacent (133).

Fertilization--External (54).

Reproductive Potential--Fecundity varies with size, region, and age and ranges from 1,400 to 5,000 eggs for the first spawning down to 10-1,000 eggs for the second (54,266). For first spawning females, fecundity increases with size. Fecundity generally is greater in Alaska than in British Columbia (54). Spawning occurs once a year and each individual mates once as a male and one or two times as a female (30,55).

Release of young--Larvae are released from December to April (55,73). Eggs hatch at night. During hatching, the female vigorously moves her pleopods while holding on to the substrate or swimming freely. Eggs hatch in batches of 5-25 with the female resting between hatching events (54). Eggs from an individual may hatch over 1-10 days (54,260). Larvae are released at depths of 70-216 m (55,102).

GROWTH AND DEVELOPMENT

Egg size--Undescribed.

Embryonic Development--Indirect and external (55). Incubation time is 4.0-5.5 months occurring sometime between September and April (55,73,102). The larval period lasts about 83 days and occurs between December and July (55,73,260). Larvae pass through nine stages of development (55).

Larval Size Range--8-19 mm (54,260).

Juvenile Size Range--20 mm to 62-134 mm TL (4 mm to 13-28 mm CL) (54,55).

Age and Size of Adults--Growth and age at maturity varies by region. Males in British Columbia waters mature at 1.5 years and are 13.0-28.0 mm CL and weigh up to 13 g (55,54); in southern California they mature at 4 years and about 40 mm CL (315). Maximum size for males is 50 mm CL, 230 mm TL, and 23.4 g (54,55,73). Individuals undergo sexual transition at 2.0-2.5 years in British Columbia (28-50 mm CL) (54,55,73,266), and 3.0-3.5 years (44 mm CL) in southern California (315). They are females at age 2.5-3.5 years (30.8-33.2 CL) in British Columbia (73,266), and age 4 years (48 mm CL) in southern California (315). Maximum age is 6 years (315) and maximum size is 270 mm TL, or about 62.5 mm CL and approximately 170 g (30,54,55).

FOOD AND FEEDING

Trophic Mode--Carnivore, detritivore.

Food Items--Spot shrimp primarily eat polychaetes (Maldanidae, Polyniodae, Nephtyidae, Sabellariidae), crustaceans such as amphipods, fish carcasses, and sponges (54,55,102).

Feeding Behavior--Spot shrimp forage on the bottom throughout the day and night (54).

BIOLOGICAL INTERACTIONS

Predation--Spot shrimp are eaten by octopus and yelloweye rockfish. Juveniles vary in color with the color of surrounding plants and hence may avoid predation by cryptic coloration (55). Laboratory observations indicate post-copulatory male predation on recently molted and mated females, especially when more than one male is present (133).

Competition--Competitors may include lithoid crabs, such as Lopholithodes foraminatus and Acantholithodes hispidus, and majid crabs such as Chorilia longipes (54).

Social Interactions--Undescribed.

Community Associations and Interactions--Undescribed.

FACTORS INFLUENCING POPULATIONS

Spot shrimp are sometimes infested with rhizocephalan barnacles (55). High mortalities of caged individuals occur during algae blooms and rapid fluctuations in water temperature (73).

Commercial fisheries represent a potential for substantial impacts on populations through various factors. These include an extensive increase in effort (e.g., four-fold increases in Prince William Sound in 1979-84 (15) and the increase from 10 permits issued in southeast Alaska in 1979 to 118 in 1984 (164)), timing of harvests (fishing during egg-bearing or larval-release periods), and focusing fishing effort on large females.

SIDESTRIPE SHRIMP, Pandalopsis dispar Rathbun, 1902 (135)

(giant red shrimp, side-stripe shrimp (55,135))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Pandalidae (29,45,135)

MANAGEMENT

Since most harvests occur in northern coastal waters, this species is managed by the State of Alaska through its Board of Fisheries and Game, with recommendations from the Alaska Department of Fish and Game. The North Pacific Fishery Management Council has identified all shrimps as prohibited species (i.e., all groundfish fisheries in the eastern Bering Sea and Gulf of Alaska must not retain any by-catch of these species) (5,213). The Canada Department of Fisheries and Oceans monitors harvests in British Columbia waters.

VALUE

Commercial--This species is one of the larger shrimps (up to 35 per pound) taken in northern waters, and is fished commercially with trawls from the western Gulf of Alaska to southern British Columbia (12,55). It is often caught incidentally while trawling for northern pink shrimp, although its landings are reported separately only when it occurs in volumes large enough to warrant sorting of catches (sidestripe shrimp commands a higher price than other shrimps). Although only 101 t were reported for 1981-83 in Alaska (12), this species has been an important component of shrimp harvests (accounting

for up to 33% of southeast Alaska catches in some years and contributing measurable amounts to landings in other areas such as the Shumagin Islands, Kodiak Island, and lower Cook Inlet). It is fished at depths of 70-150 m (55,135) and current important harvest regions are Yakutat Bay on the northern Gulf of Alaska coast and the Stikine River Flats/Duncan Canal area of southeast Alaska (12). Commercial quantities have been reported for British Columbia waters in Chatham Strait along the northern mainland coast, Howe Sound and English Bay near the city of Vancouver, Stuart Channel along the southeastern coast of Vancouver Island, and in Barkley Sound on the west coast of Vancouver Island (42,55). This species has an excellent flavor and is sold whole or peeled and cooked (135). As with other shrimps along the west coasts of Canada and the United States, sidestripe shrimp is harvested only by domestic fishermen.

Recreational--This species does not support an large recreational fishery, especially since most sport fishing for shrimp is done with pots and this species rarely is caught in baited pots (55).

Ecological--It is one of the four most abundant large shrimp species on soft bottoms of the continental shelf from British Columbia to the Gulf of Alaska (42,86).

RANGE

Worldwide--Sidestripe shrimp is a boreal, eastern Pacific species with a distribution that is entirely within the region of the Data Atlas.

Within Study Area--It is found from lat. 61°N in the eastern Bering Sea (west of St. Matthew Island) (344) south to Manhattan Beach, Oregon (55). Incidental catches are also reported in NMFS survey data as far south as Fort Bragg, California, but specimen identification cannot be verified. It should also be noted that this species is found only along the outer shelf and

continental slope in the eastern Bering Sea (344); it primarily occurs on the inner shelf in all other regions.

LIFE MODE

Eggs are brooded on the pleopods of the female. Larvae are pelagic whereas juveniles and adults are benthopelagic (55,86).

HABITAT

Type--Larvae are probably neritic. Juveniles and adults are sublittoral-bathyal, occur from 38-649 m (28,55,135), and over 90% of their occurrences in NMFS resource assessment surveys have been at 50-300 m (344). In the northern portion of its range (i.e., Bering Sea), 95% of the occurrences of sidestripe shrimp has been at depths of 250-600 m (344).

Substrate--Larvae are found in the water column (86). Juveniles and adults occur on green mud bottoms (and sometimes rocks) when not in the water column (28,135).

MIGRATIONS AND MOVEMENTS

Undescribed.

POPULATION CHARACTERISTICS

Undescribed.

REPRODUCTION

Mode--Sexual, protandric hermaphrodites, oviparous (55).

Mating--Occurs in late October (55), though locations are undescribed.

Fertilization--External (55).

Reproductive Potential--This species produces approximately 900-4,150 eggs per female. Fecundity is highest in Alaska and lowest in Puget Sound. Each individual spawns once as a male and once as a female (55).

Release of Young--Larval release occurs in March-April (55).

GROWTH AND DEVELOPMENT

Egg Size--Undescribed.

Embryonic Development--Indirect and external. At fertilization, the eggs are glued to the pleopods of the female and brooded until they hatch about 5.5 months later. Larvae pass through five to six zoeal stages and metamorphose into juveniles in late July-August (55).

Larval Size Range--10-30 mm TL (86).

Age and Size of Adults--Males mature during their second autumn (23.5 months after fertilization; 18 months after hatching) at a size of 21.6 mm CL and weigh 6.5 g. Mating occurs shortly thereafter (in autumn). Sex transformation begins the following spring, occurring in 5-6 stages, and is completed by the end of summer. Females mature by their third autumn, measuring 29.3 mm CL and weighing about 16 g. After mating, the females brood their eggs until the following spring and generally die soon after the eggs have hatched. Maximum age is less than 4 years (55). Maximum size for females is 39 mm CL, 208 mm TL, and 20 g (28,135). Maximum size for males is about 31 mm CL and 182 mm TL. (55).

FOOD AND FEEDING

Trophic mode--Undescribed.

Food items--Undescribed. The food items of sidestripe shrimp are possibly similar to the food items of other pandalid shrimps. However, unlike other

pandalid shrimps, it is apparently not attracted to the typical bait used in shrimp pots.

Feeding behavior--Undescribed.

BIOLOGICAL INTERACTIONS

Predators--It is eaten by Pacific cod in the western Gulf of Alaska (17).

Competition--Undescribed.

Social Interactions--Undescribed.

Community Associations and Interactions--Undescribed.

FACTORS INFLUENCING POPULATIONS

A small proportion (less than 3%) is reported to have branchial chamber infestations by the epicaridean isopod, Bopyroides hippolytes. This infestation retards growth and delays sex transformation (55). Commercial fisheries are probably a large source of mortality.

RIDGEBACK PRAWN, Sicyonia ingentis (Burkenroad, 1938) (135)

(Japanese rock shrimp, Pacific rock shrimp, rock shrimp, Japanese shrimp (135,251,285))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Sicyoniidae (29,45,135)

MANAGEMENT

Ridgeback prawn is managed in California waters by the California Department of Fish and Game (281).

VALUE

Commercial--Ridgeback prawn is fished commercially with trawls from Point Conception to Ventura, California, and at Magadalena Bay, Baja California Sur (251,314,346). In U.S. waters, it is fished from October to May, but is taken incidentally in spot prawn catches during the closed season (i.e., June to September) (314). Catches are greatest from November to March, and an average of 71.0 t were taken during 1981-83 (58). Fishing depths are 55-180 m in Santa Barbara Channel (102,316). Ridgeback prawn is recruited to the fishery at age 1 year (60). This species is marketed as fresh or frozen tails. During the summer, the gonads extend back into the abdomen (tail) and give this shrimp a disagreeable appearance (102,316). [Authors' update: ridgeback prawn harvests increased to 392 t by 1985; ex-vessel value was $528,000 (186).]

Recreational--Not important recreationally.

Ecological--This species is the most abundant large shrimp on the middle and outer continental shelf of southern California and northern Baja California. It is locally abundant in sediments near sewage outfalls (346). Ridgeback prawn is the largest species of sicyonid shrimp in the eastern Pacific and the northernmost-distributed member of its genus (251).

RANGE

Worldwide--Ridgeback prawn is a warm-temperate, eastern Pacific (Californian) species that occurs from central California to Isla Maria Madre and Nayarit, Mexico. Its range includes the southern half of the Gulf of California (251).
Within Study Area--It occurs from off Moss Landing, California, to Cabo San Lucas, Baja California Sur, and along both the west and east shores of the Gulf of California up to the southern end of Isla Tiburon (251).

LIFE MODE

Eggs and larvae are pelagic, whereas juveniles and adults are benthic (313,340).

HABITAT

Type--Eggs and larvae are neritic (347). Juveniles and adults are sublittoral, occurring from 5 to 307 m (251). Juveniles are most abundant from 25 to 50 m and adults are abundant from about 45 to 180 m (251,316,346).
Substrate--Juveniles and adults occur on sand, shell, and green mud bottoms, but seem to prefer sandy substrate. Commercial fisheries target the concentrations located on the sandy substrate (251).

Physical/Chemical--This species lives in euhaline waters of 26-35 ppt and at temperatures of 4-30°C (251).

MIGRATIONS AND MOVEMENTS

Ridgeback prawn move into deeper water as they grow; hence, mature individuals are found further offshore than juveniles (21). Vertical movements and movements along the coast are undescribed.

POPULATION CHARACTERISTICS

Undescribed.

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (347).

Mating--This occurs from May to October and at depths of 145 m off Santa Barbara, California (251). Mating behavior is undescribed but is known to involve copulation (347).

Fertilization--External and occurs as eggs are extruded (340), presumably during the summer (102).

Reproductive Potential--Fecundity is estimated at 47,000 to 131,000 eggs per spawning (22). The ridgeback prawn is apparently capable of repeated spawning throughout the spawning season (316).

Release of young--The eggs presumably hatch during the summer (102).

GROWTH AND DEVELOPMENT

Egg size--Undescribed.

Embryonic Development--Indirect and external. Incubation time is unknown, but it is probably short. Larvae initially occur in the nauplius stage (an earlier stage than caridean shrimp) (340). The duration of the pelagic larval stages is undescribed.

Larval Size Range--Undescribed.

Juvenile Size Range--About 1 mm CL to 20-23 mm (316).

Age and Size of Adults--Ridgeback prawn matures at about 20-23 mm (CL) and grows to a maximum size of about 38 mm (CL) for males and 45 mm (CL) for females (316). Females may grow to 54 mm (156 mm TL) (251,316). Size at maturity for males is not known. Maximum ages for both sexes are also not known, but they are at least 4 years (314).

FOOD AND FEEDING

Trophic Mode--Detritivore, omnivore (102,194).

Food Items--This species feeds on detritus, diatoms, sponges, polychaetes, turrid and pyramidellid snails, and crustaceans such as copepods, philomedid ostracods, amphipods, and euphausiids (194,313).

Feeding Behavior--Undescribed; presumably at least some foraging occurs on the bottom. Prey is probably captured and brought to the mouth by the pereiopods. Time of foraging is unknown.

BIOLOGICAL INTERACTIONS

Predation--It is eaten by bigmouth and slender soles (18). Like other shrimps, ridgeback prawn detects approaching predators with its extended antennae and darts backward.

Competition--Undescribed; presumably competes with yellowleg shrimp and other sicyonid shrimps where their ranges overlap.

Symbiotic Relationships--Undescribed.

Social Interactions--Undescribed.

Community Associations and Interactions--Undescribed.

FACTORS INFLUENCING POPULATIONS

Ridgeback prawn abundance increases near sewage outfalls, presumably because of sediments and food (346). Large-scale fishery depletion may be unlikely since existing laws restrict trawling in southern California only to specific areas.

CALIFORNIA SPINY LOBSTER, Panulirus interruptus (Randall,1839) (71,280)

(Langosta in Mexico; California lobster, crawfish, crayfish, lobster, red lobster, spiny lobster, and West Coast lobster. (280))

CLASSIFICATION

Phylum--Crustacea

Class--Malacostraca

Order--Decapoda

Family--Palinuridae (29,45,49)

MANAGEMENT

California spiny lobster is managed as a targeted species by the California Department of Fish and Game (64,281) in California waters and by the Departmento de Pesca in waters off Mexico.

VALUE

Commercial--California spiny lobster is fished commercially in southern California and along the outer coast of Baja California by traps set on the bottom (43,102). It is highly valued because of its taste and size; it is sold fresh, either alive or cooked (342). In the United States it is fished on almost all rocky reefs south of Point Conception, except for several closed areas (102). In Mexican waters it is probably fished along much of the Baja California coast down to Magdalena Bay, Baja California Sur, but mostly at Tortugas Bay, Baja California Sur (246). It is also fished commercially off Guadalupe Island and only incidentally taken along the Gulf of California coast (246).

The California fishery occurs from October to March at depths of 5-33 m (153,246,281). About 200 t are commercially taken in California each year

(1981-85 average, 213 t (184)) and about 1,100 t each year are taken off Baja California, most of which is exported to the United States (43). The U.S. catch annually is worth up to $1.9 million to fishermen (184). Attempts to culture this species have been unsuccessful because the larvae fail to develop completely in captivity (322).

Recreational--This species supports a large recreational fishery in southern California. Sport catches may be as much as 50% of the entire harvest for the area (102). This species is taken primarily by hand but also by baited hoop nets (64,102). In the United States, it is fished from Point Conception to the Mexican border from October to March at depths of 5-33 m (64,153,246). Recreational harvests are illegal in Mexico (101).

Ecological--California spiny lobster is a dominant benthic omnivore and also cleans ectoparasites from fishes (321).

RANGE

Worldwide--California spiny lobster is a warm-temperate (primarily San Diegan), northeastern Pacific species. It ranges from Monterey, California, to Manzanillo, Colima and occurs in the Gulf of California (102,154). Records south of Magdalena Bay are relatively rare.

Within Study Area--This species is found primarily from Point Conception, California to Magdalena Bay, Baja California Sur (154). It is occasionally found from Magdalena Bay around the southern tip of Baja California and up the east coast at least to Canal el Ballenas. The only apparent areas of moderate abundance along the gulf coast are at Isla Cerralvo and in the Isla Angel de la Guarda-Canal de Ballenas areas (31). It is also found off Isla Guadalupe (246). Larvae and juveniles are rarely found north of southern California to Monterey (154,178,280).

LIFE MODE

Eggs are brooded on the pleopods of the female (153). The larvae are pelagic; juveniles and adults are primarily benthic, although occasionally they have been seen swimming at the surface (154,252,282,342).

HABITAT

Type--Phyllosoma larvae are neritic-epipelagic, and occur offshore to 530 km and at depths from the surface to 137 m (155,342). The puerulus (late stage) larvae are neustonic in neritic waters (282). For the first 2 years, juveniles are found from the intertidal zone to 5 m (125,126). Subadults and adults are found from the intertidal zone to 80 m (102,173,321). Egg-bearing females are found at depths of 0.3-14 m (153).

Substrate--For the first 2 years juveniles live in surfgrass beds, but subadults are found in mussel beds and subtidal rock crevices (126). Adults are found in rocky areas and crevices (often in kelp beds) during the day (253). At night they may occur on sandy bottoms, but never on mud (173).

Physical/Chemical--California spiny lobster occur in euhaline waters. Larvae, and presumably other life stages, are found in waters with temperatures of 12.5-25.0°C (252).

MIGRATIONS AND MOVEMENTS

Small juveniles do not move far (173). Subadults of 3 years or older and adults occur at depths less than 10 m from April to May, but move to depths of 10-30.0 m in September-October after molting in order to mate (126). They remain there until spring and then migrate inshore (126). During inshore-offshore movements, clusters of 15 or more individuals may be found together on the sand. These movements occur only after dark (321). Random movements are less than 8 km (173).

POPULATION CHARACTERISTICS

Undescribed.

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (173).

Mating--California spiny lobsters mate from November to May at depths of 10-30 m in the area from the Channel Islands to Magdalena Bay, including offshore banks and probably Isla Guadalupe; some mating also occurs in the Gulf of California (155,173,196,246). Males are territorial at this time and dig caves beneath rocks by removing sand, and then aggressively chase away other males (173,321). The female initiates mating by crawling beneath the male so that their ventral surfaces are in contact. The female curls her abdomen and telson inside those of the male (173). The male then deposits a puttylike mass of spermatophores onto the ventral thorax of the female. Mating with immature females is sometimes attempted (342).

Fertilization--External (126). After mating, the female moves inshore for oviposition, storing the sperm until the eggs are extruded. During oviposition, the female mechanically breaks open the sperm packet and then extrudes eggs for fertilization. Only fertilized eggs attach to the pleopods (173). This process occurs from March to July at depths less than 10 m (126,173).

Reproductive Potential--Fecundity varies with size: 50,000 eggs at 203 mm TL to 832,000 eggs at 430 mm (173,342). Each female reproduces once a year (173).

Release of young--Larvae are released from June to December (primarily August-September) at depths of 0.3-14 m (154,155,173). Release stops later in the south than in the north (155).

GROWTH AND DEVELOPMENT

Egg size--Undescribed.

Embryonic Development--Indirect and external (102). Incubation time of eggs is 9-10 weeks and occurs from March through December (153,154,342). The larval period lasts 5-10 months; larvae can be found throughout the year (earliest stages occur June-December) (154,282). Juveniles first appear in June-August (282).

Larval size range--1-2 mm to 2.3-3.2 mm (180,154,173).

Juvenile size range--2.3-3.2 mm to 170-255 mm TL (180,154,173).

Age and Size of Adults--Males grow faster than females after maturity, live longer, and achieve a larger size (173). Males and females mature at 5 years; females mature at 170-235 mm TL (about 66-69 mm CL) and males at 190-255 mm TL (102,173). Females live for at least 17 years and reach a maximum size of 500 mm TL and 5.5 kg. Males probably live for at least 30 years and reach a maximum size of 910 mm TL and 15.8 kg (173).

FOOD AND FEEDING

Trophic Mode--Omnivore; both predator and scavenger (246,342).

Food Items--Phyllosoma larvae eat soft-bodied prey such as hydromedusae, ctenophores, chaetognaths, and fish larvae (252,322). Subadults and adults eat a wide range of benthic prey, including algae, molluscs (e.g., abalones, mussels, clams), snails, sponges, lobsters, sea urchins, and fish (102,173, 180,246,321,342).

Feeding behavior--Larvae feed in the water column (252,322). Subadults and adults are benthic foragers (342). Typically, they crawl forward through eelgrass or algae while looking for prey (180). Prey is located by sight and smell (which is sensed by the antennules) (173). Feeding occurs at night from

dusk to dawn (126). California spiny lobster is not active on moonlit nights; females may feed less when they are ovigerous (173,180).

BIOLOGICAL INTERACTIONS

Predation--Major predators of the California spiny lobster are cabezon, kelp bass, and California sheephead. It is also eaten by octopus, horn shark, leopard shark, California moray, California scorpionfish, rockfishes, and giant sea bass (173,196,342). It is also cannibalistic (342).

Subadults and adults hide in rock dens during the day to avoid predators, but smaller juveniles rely on cryptic coloration and burrow slightly or lie appressed to the sand in surfgrass beds (126,157). They also rely on their spiny bodies and hard shells for protection, and point their spiny antennae at attackers and make a noise with the stridulating apparatus of their antennae (153,180). They can swim backwards rapidly by flexing their abdomens to escape and may lose appendages for defense if caught (173).

Competition--Cancrid crabs replace California spiny lobster in offshore areas when the lobsters move inshore in March (321). Based on laboratory observations, introduction of the American lobster, Homarus americanus, to the west coast would probably be detrimental to California spiny lobster because the American lobster is more aggressive (168).

Symbiotic Relationships--Between molts, the hard exoskeleton provides a substrate for attachment of sponges, hydroids, serpulid polychaetes, and barnacles. A pleustid amphipod, Parapleustes commensalis, is found commensally on the pleopods of mature females (173). Ectoparasites are cleaned from California spiny lobster by red rock shrimp (lysmata californica). It in turn cleans ectoparasites from fishes entering its caves (71,321).

Social Interactions--Smaller individuals are gregarious and tend to move and forage in groups. Juveniles occur in large concentrations along ledges, in caves, and in eelgrass. Individuals of 25-35 cm in length occur in groups of 3-12, but larger individuals are solitary (173). Males are territorial and aggressively chase other males. Dominance is maintained by repeated contact; the largest get the shelter (26).

Community Associations and Interactions--This species is typically found on reefs and near giant kelp (Macrocystis spp.) and feather-boa kelp (Egregia spp.), coralline algae, and sea grasses (Phyllospadix spp. and Zostera marina) (173).

FACTORS INFLUENCING POPULATIONS

Larvae experience a high rate of mortality because of their small size and sensitivity to temperatures; they die at temperatures below 12.5°C (155,252,282). High temperatures increase the rate of molting for juveniles and adults, but decrease the size increase per molt (157). High mortality occurs during ecdysis because of unsuccessful exoskeleton shedding (173). The gills are often infested with a poecilasmatid barnacle (212). During red tides, lobsters perish when they attempt to avoid waters with low oxygen by moving up onto beaches (173). Declines of lobster stocks off California are largely due to poaching of undersized individuals (43).

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APPENDIX A.--PLACE NAMES GAZETTEER FOR SPECIES SYNOPSES.

Place	Nation	State or Province	Latitude	Longitude
Adak Island	USA	Alaska	5200.00N	17645.00W
Adak Strait	USA	Alaska	5147.00N	17700.00W
Admiralty Inlet	USA	Washington	4806.00N	12241.00W
Afognak Island	USA	Alaska	5815.00N	15230.00W
Agate Pass	USA	Washington	4743.00N	12233.50W
Agattu Island	USA	Alaska	5220.00N	17325.00W
Aialik Bay	USA	Alaska	5940.00N	14934.00W
Alaska Peninsula	USA	Alaska	5615.00N	15920.00W
Albatross Bank	USA	Alaska	5630.00N	15230.00W
Aleutian Islands	USA	Alaska	5150.00N	17700.00W
Alitak Bay	USA	Alaska	5653.00N	15110.00W
Alitak Flats	USA	Alaska	5646.00N	15450.00W
Alsea River (and Bay)	USA	Oregon	4425.00N	12403.00W
Aleutian Basin	USA	Alaska	5500.00N	16300.00W
Aleutian Trench	USA	Alaska	5027.00N	17610.00E
Amchitka Island	USA	Alaska	5111.00N	17855.00E
Amukta Pass	USA	Alaska	5230.00N	17200.00W
Anacapa Island	USA	California	3400.00N	11920.00W
Arguello Canyon	USA	California	3422.00N	12100.00W
Ascunsion Island (Also Isla Ascunsion)	Mexico	Baja Calif. Sur	2706.50N	11417.50W
Astoria Bay	USA	Oregon	4613.00N	12345.00W
Astoria Canyon	USA	Oregon	4611.00N	12438.00W
Attu Island	USA	Alaska	5304.00N	17250.00E
Augustine Island	USA	Alaska	5918.00N	15326.00W
Báhia Asunción (Also Ascunsion Bay)	Mexico	Baja Calif. Sur	2810.00N	11420.00W
Báhia Ballenas (Also Ballenas Bay)	Mexico	Baja Calif. Sur	2645.00N	11327.00W
Báhia Concepcion (Also Concepcion Bay)	Mexico	Sonora	2655.00N	11150.00W
Baja California Norte	Mexico	---	2925.00N	11430.00W
Baja California Sur	Mexico	---	2630.00N	11220.00W
Baranof Island	USA	Alaska	5645.00N	13510.00W
Barkley Sound	Canada	British Columbia	4850.00N	12516.00W
Bear Seamount	---	---	4603.00N	13012.00W
Bechevin Bay	USA	Alaska	5500.00N	16323.00W
Bellingham Bay	USA	Washington	4900.00N	12249.00W
Bering Sea	---	---	5800.00N	16600.00W
Bering Strait	USSR/USA	---	6555.00N	16850.00W
Bodega Bay	USA	California	3821.00N	12303.20W
Bodega Head	USA	California	3818.00N	12313.20W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
Bolinas Lagoon	USA	California	3802.00N	12255.00W
Bowie Canyon	---	---	5237.00N	17910.00E
Bowie Seamounts	---	---	5320.00N	13540.00W
Bowers Bank	USA	Alaska	5415.00N	17930.00E
Bowers Basin	USA	Alaska	5315.00N	17700.00E
Bowers Canyon	USA	Alaska	5310.00N	17910.00W
Bowers Ridge	USA	Alaska	5435.00N	17800.00E
Bristol Bay	USA	Alaska	5752.00N	15905.00W
British Columbia	Canada	---	5355.00N	12259.00W
Brookings	USA	Oregon	4204.00N	12417.00W
Budd Inlet	USA	Washington	4659.00N	12255.00W
Burrad Inlet	Canada	British Columbia	4915.00N	12306.00W
California	USA	---	3717.00N	12029.00W
Canal De Ballenas	Mexico	Baja Calif. Norte	2900.00N	11321.00W
Cape Alava	USA	Washington	4810.00N	12444.00W
Cape Blanco	USA	Oregon	4250.20N	12433.80W
Cape Chacon	USA	Alaska	5438.00N	13200.00W
Cape Douglas	USA	Alaska	5853.00N	15318.00W
Cape Elizabeth	USA	Washington	4722.00N	12418.00W
Cape Fairweather	USA	Alaska	5849.00N	13759.00W
Cape Flattery	USA	Washington	4823.50N	12441.10W
Cape Gamova	USSR	---	4232.00N	13112.00E
Cape Igvak	USA	Alaska	5727.00N	15600.00W
Cape Johnson	USA	Washington	4758.00N	12440.00W
Cape Kasilof	USA	Alaska	6022.00N	15122.00W
Cape Mendocino	USA	California	4026.40N	12424.30W
Cape Mordvinof	USA	Alaska	5455.00N	16439.00W
Cape Muzon	USA	Alaska	5433.00N	13240.00W
Cape Navarin	USSR	---	6216.00N	17910.00E
Cape Nukshak	USA	Alaska	5823.30N	15358.45W
Cape Nushagak	USA	Alaska	5843.00N	15829.00W
Cape Ommaney	USA	Alaska	5610.00N	13440.00W
Cape Perpetua	USA	Oregon	4415.50N	12406.50W
Cape San Lucas (Also Cabo San Lucas)	Mexico	Baja Calif. Sur	2245.00N	10959.00W
Cape Seniavin	USA	Alaska	5624.00N	16012.00W
Cape Shoalwater	USA	Washington	4644.00N	12406.00W
Cape Spencer	USA	Alaska	5814.00N	13640.00W
Cape Suckling	USA	Alaska	6000.00N	14350.00W
Carmel	USA	California	3633.00N	12155.00W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
Carr Inlet	USA	Washington	4715.00N	12240.00W
Cascadia Seamount	---	---	4640.00N	12720.00W
Case Inlet	USA	Washington	4718.00N	12243.00W
Cayucos	USA	California	3528.00N	12054.00W
Cedros Island (Also Isla Cedros)	Mexico	Baja Calif. Norte	2825.00N	11510.00W
Channel Islands	USA	California	3342.00N	12000.00W
Chatham Sound	Canada	British Columbia	5418.00N	13017.00W
Chatham Strait	USA	Alaska	5703.00N	13432.00W
Chichagof Island	USA	Alaska	5730.00N	13530.00W
Chignik Bay	USA	Alaska	5622.00N	15820.00W
Chiniak Bank	USA	Alaska	5739.00N	15210.00W
Chirikof Island	USA	Alaska	5545.00N	15540.00W
Chilkoot Inlet	USA	Alaska	5900.00N	13513.00W
Chukchi Sea	---	---	6800.00N	17000.00W
Clatsop Beach	USA	Washington	4610.00N	12357.00W
Clayoquot Sound	Canada	British Columbia	4915.00N	12600.00W
Cobb Seamount	---	---	4645.00N	13050.00W
College Fjord	USA	Alaska	6100.00N	14801.00W
Columbia River	USA	Alaska	4618.00N	12330.00W
Commander Islands (Also Kommandorsky Islands)	USSR	---	5500.00N	16700.00E
Cook Inlet	USA	Alaska	5905.00N	15230.00W
Coos Bay	USA	Oregon	4323.00N	12421.00W
Copalis Beach	USA	Washington	4707.00N	12411.00W
Copper River	USA	Alaska	6042.00N	14430.00W
Cordel Bank	USA	---	3801.00N	12326.00W
Cordova Bay	USA	Alaska	6036.00N	14636.00W
Coronation Gulf	USA	Alaska	6800.00N	11200.00W
Cortez Bank	USA	---	3225.00N	11915.00W
Crescent City	USA	California	4144.20N	12411.40W
Dall Island	USA	Alaska	5500.00N	13329.00W
Dana Passage	USA	Washington	4714.00N	12250.00W
Dana Point	USA	California	3320.75N	11743.00W
Davidson Bank	USA	---	5355.00N	16410.00W
Davidson Inlet	USA	Alaska	5603.00N	13329.00W
Davidson Seamount	---	---	3545.00N	12242.00W
Delgada Canyon	USA	---	4004.00N	12409.00W
Dellwood Seamounts	---	---	5030.00N	13030.00W
Destruction Island	USA	Washington	4740.50N	12429.00W
Dixon Entrance	USA/CAN	---	5427.00N	13300.00W
Douglas Channel	Canada	British Columbia	5327.00N	12918.00W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
Dungeness Spit	USA	Washington	4812.00N	12311.00W
El Canyon	USA	---	4037.00W	12431.00W
Eickenberg Ridge	---	---	4835.00N	13320.00W
Eickenberg Seamount	---	---	4830.00N	13307.00W
Elkhorn Slough	USA	California	3655.00N	12154.00W
English Bay	Canada	British Columbia	4917.00N	12310.00W
Ensenada	Mexico	Baja Calif. Norte	3152.00N	11637.00W
Ernest Sound	USA	Alaska	5611.00N	13218.00W
Explorer Seamount	---	---	4903.00N	13056.00W
Fairweather Grounds	USA	Alaska	5820.00N	13850.00W
Farallon Islands	USA	California	3740.00N	12300.00W
Fitzhugh Sound	Canada	British Columbia	5137.00N	12756.00W
Fraser River	Canada	British Columbia	4910.00N	12320.00W
Frederick Sound	USA	Alaska	5650.00N	13425.00W
Freshwater Bay	USA	Alaska	5751.00N	13459.00W
Gilbert Seamount	---	---	5230.00N	15000.00W
Glacier Bay	USA	Alaska	5840.00N	13627.00W
Gorda Valley	USA	California	3952.00N	12503.00W
Graham Island	Canada	British Columbia	5352.00N	13232.00W
Grayland	USA	Washington	4648.00N	12405.00W
Grays Harbor	USA	Washington	4653.30N	12406.90W
Guadalupe Island (Also Isla Guadalupe)	Mexico	Baja Calif. Norte	2845.00N	11820.00W
Gulf Islands	Canada	British Columbia	4910.00N	12355.00W
Gulf of Alaska	---	---	5600.00N	14500.00W
Gulf of Anadyr	USSR	---	6430.00N	17830.00W
Gulf of California	Mexico	---	2640.00N	11050.00W
Guide Seamount	---	---	3704.00N	12320.00W
Gumdrop Seamount	---	---	3731.00N	12328.00W
Halfmoon Bay	USA	California	3731.00N	12231.00W
Hallo Bay	USA	Alaska	5827.00N	15357.00W
Hawaii	USA	---	1930.00N	15530.00W
Hawley Ridge	---	---	5100.00N	17630.00W
Heceta Bank	USA	Oregon	4406.00N	12452.00W
Hecate Strait	Canada	British Columbia	5300.00N	13100.00W
Heck Seamount	---	---	4820.00N	12950.00W
Herendeen Bay	USA	Alaska	5543.00N	16050.00W
Hinchinbrook Entrance	USA	Alaska	6020.00N	14650.00W
Hokkaido Island	Japan	---	4300.00N	14300.00E
Homer (Homer Spit)	USA	Alaska	5938.00N	15133.00W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
Honshu	Japan	---	3603.00N	13800.00E
Hood Canal	USA	Washington	4730.00N	12230.00W
Howe Sound	Canada	British Columbia	4936.00N	12317.00W
Hueneme	USA	California	3409.00N	11912.50W
Humboldt County	USA	California	4050.00N	12350.00W
Humboldt Bay	USA	California	4045.90N	12413.70W
Huntington Beach	USA	California	3340.00N	11800.00W
Icy Strait	USA	Alaska	5820.00N	13545.00W
Isla Angel De La Guarda	Mexico	Baja Calif. Sur	2916.00N	11322.00W
Isla María Madre	Mexico	Nayarit	2135.00N	10615.00W
Isla Natividad	Mexico	Baja Calif. Sur	2750.00N	11510.00W
Isla Tiburon	Mexico	Baja Calif. Sur	2900.00N	11221.00W
Izembeck Lagoon (Bay)	USA	Alaska	5520.00N	16248.00W
Jalisco	---	---	2022.00N	10350.00W
Johnstone Strait	Canada	British Columbia	5022.00N	12559.00W
Juan De Fuca Canyon	USA/Can.	---	4800.00N	12520.00W
Juneau	USA	Alaska	5820.00N	13420.00W
Kachemak Bay	USA	Alaska	5932.00N	15152.00W
Kalaloch	USA	Washington	4736.30N	12422.70W
Kalekta Bay	USA	Alaska	5359.00N	16620.00W
Kamchatka Peninsula	USSR	---	5700.00N	16000.00E
Kanak Island	USA	Alaska	6008.00N	14421.00W
Kenai Peninsula	USA	Alaska	6008.00N	15010.00W
Ketchikan	USA	Alaska	5520.30N	13138.45W
Kilisut Harbor	USA	Washington	4803.00N	12242.50W
Kingcome Inlet	Canada	British Columbia	5046.00N	12623.00W
Kiska Island	USA	Alaska	5150.00N	17723.00E
Knight Inlet	Canada	British Columbia	5038.00N	12634.00W
Knight Island Passage	USA	Alaska	6020.00N	14800.00W
Kobuk River	USA	Alaska	6655.00N	15910.00W
Kodiak	USA	Alaska	5750.00N	15210.00W
Kodiak Island	USA	Alaska	5728.00N	15334.00W
Kodiak Seamounts	---	---	5500.00N	13930.00W
Kommandorskiye Basin	---	---	5720.00N	16700.00E
Koryak Coast	USSR	---	6120.00N	17335.00E
Kotzebue Sound	USA	Alaska	6627.00N	16300.00W
Kruzof Island	USA	Alaska	5710.00N	13540.00W
Kyuquot Sound	Canada	British Columbia	4948.00N	12717.00W
Kvichak	USA	Alaska	5858.00N	15656.00W
Kyushio	Japan	---	3242.00N	13111.00E
Kyushu Island	Japan	---	3242.00N	13111.00E

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
La Jolla	USA	California	3250.00N	11717.00W
La Jolla Canyon	USA	California	3258.00N	11732.00W
La Paz	Mexico	Baja Calif. Sur	2405.00N	10939.00W
La Perouse Bank	---	---	4835.00N	12548.00W
Little Diomede Island	USA	Alaska	6545.00N	16855.00W
Lituya Bay	USA	Alaska	5836.45N	13739.30W
Long Beach	USA	California	3346.00N	11810.00W
Long Beach	Canada	British Columbia	4900.00N	12539.00W
Los Angeles Harbor	USA	Alaska	3333.00N	11816.00W
Los Coronados Islands	Mexico	Baja Calif. Norte	3229.00N	11718.00W
Lynn Canal	USA	Alaska	5850.00N	13515.00W
Magdalena Bay (Also Báhia Magdalena)	Mexico	Baja Calif. Sur	2440.00N	11200.00W
Makushin Bay	USA	Alaska	5340.00N	16700.00W
Malibu Point	USA	California	3402.00N	11841.00W
Malispina Strait	Canada	British Columbia	4930.00N	12404.00W
Manhattan Beach	USA	California	3344.00N	11824.00W
Manzanillo	Mexico	Colima	1900.00N	10420.00W
Marina Del Rey	USA	California	3350.00N	11825.00W
Mattole Canyon	---	---	4018.00N	12424.00W
Mazatlan	Mexico	Sin	2313.00N	10625.00W
Mendocino Canyon	---	---	4028.00N	12427.00W
Mendocino County	USA	California	3930.00N	12330.00W
Mendocino Ridge	---	---	4024.00N	12734.00W
Middle Canyon	---	---	5830.00N	17605.00W
Milbanke Sound	Canada	British Columbia	5215.00N	12854.00W
Mission Bay	USA	California	3247.00N	11713.00W
Mocrocks Beach	USA	Washington	4714.50N	12413.00W
Montague Island	USA	Alaska	5942.00N	14720.00W
Monterey (Bay)	USA	Alaska	3635.00N	12156.00W
Monterey Canyon	---	---	3638.00N	12217.00W
Morro Bay	USA	California	3521.80N	12052.10W
Morzhovoi Bay	USA	Alaska	5500.00N	16300.00W
Navarin Ridge	---	---	5840.00N	17645.00W
Navarin Canyon	---	---	6010.00N	17810.00W
Navarro Canyon	---	---	3906.00N	12406.00W
Nayarit (State)	Mexico	---	2200.00N	10500.00W
Netarts Bay	USA	Oregon	4524.00N	12357.00W
Newport	USA	Oregon	4439.00N	12404.00W
Newport Bay	USA	California	3333.00N	11745.00W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
Nome	USA	Alaska	6433.00N	16500.00W
Nootka Sound	Canada	British Columbia	4942.00N	12650.00W
Norton Sound	USA	Alaska	6400.00N	16400.00W
Noyo Canyon	---	---	3930.00N	12425.00W
Nuka Bay	USA	Alaska	5919.00N	15033.00W
Nunivak Island	USA	Alaska	6007.00N	16600.00W
Observatory Inlet	Canada	British Columbia	5510.80N	12940.75W
Ocean Bay	USA	Alaska	5705.00N	15310.00W
Ocean Shores	USA	Washington	4700.00N	12410.00W
Olga Bay	USA	Alaska	5705.00N	15425.00W
Olympia	USA	Washington	4703.00N	12254.00W
Olyutorskii Bay	USSR	---	6000.00N	16800.00E
Oregon	USA	---	4400.00N	12100.00W
Oyster Bay	Canada	British Columbia	4955.00N	12511.00W
Pathfinder Seamount	---	---	5055.00N	14320.00W
Palos Verdes Peninsula	USA	California	3347.00N	11817.00W
Pacific Beach	USA	Washington	3248.00N	11715.50W
Parks Seamount	USA	California	4413.00N	12955.00W
Patton Seamount	---	---	5430.00N	14900.00W
Pavlof Bay	USA	Alaska	5530.00N	16130.00W
Pendrell Sound	Canada	British Columbia	5015.00N	12444.00W
Petersburg	USA	Alaska	5648.00N	13258.00W
Petrel Bank	---	---	5208.00N	17948.00W
Pervenets Canyon	---	---	5925.00N	17800.00W
Pervenets Ridge	---	---	6000.00N	17740.00W
Pioneer Canyon	---	---	3725.00N	12314.00W
Pioneer Seamount	---	---	3718.00N	12320.00W
Pismo Beach	USA	California	3510.00N	12037.00W
Point Arena	USA	California	3857.00N	12343.00W
Point Arguello	USA	California	3435.00N	12039.00W
Point Baja (Also Punta Baja)	Mexico	Baja Calif. Norte	3000.00N	11550.00W
Point Barrow	USA	Alaska	7132.00N	15630.00W
Point Buchon	USA	California	3515.00N	12045.00W
Point Conception	USA	California	3423.90N	12028.20W
Point Descanso (Also Punta Descanso)	Mexico	Baja Calif. Norte	3200.00N	11650.00W
Point Dume	USA	California	3400.00N	11848.00W
Point Hope	USA	Alaska	6820.00N	16750.00W
Point Lobos	USA	California	3746.50N	12235.00W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
Point Loma	USA	California	3240.00N	11714.50W
Point Montara	USA	California	3732.00N	12231.00W
Point Mugu	USA	California	3410.00N	11913.00W
Point Pinos	USA	California	3638.00N	12156.00W
Point Reyes	USA	California	3759.00N	12259.00W
Point San Juanico (Also Punta San Juanico)	Mexico	Baja Calif. Sur	2603.00N	11218.00W
Polly Creek	USA	Alaska	6017.00N	15227.00W
Port Frederick	USA	Alaska	5813.00N	13530.00W
Port Moller	USA	Alaska	5559.30N	16034.30W
Port Orchard	USA	Washington	4700.00N	12236.00W
Port Susan	USA	Washington	4810.00N	12220.50W
Port Townsend	USA	Washington	4809.00N	12248.00W
Port Wells	USA	Alaska	6048.00N	14814.00W
Portlock Bank	USA	---	5823.00N	15005.00W
Possession Sound	USA	Washington	4800.00N	12220.00W
Powell River	Canada	British Columbia	4954.00N	12434.00W
President Jackson Seamount	---	---	4232.00N	12747.00W
Pribilof Canyon	USA	---	5610.00N	16904.00W
Pribilof Islands	USA	Alaska	5700.00N	17000.00W
Prince of Wales Island	USA	Alaska	5551.00N	13258.00W
Prince Rupert	Canada	British Columbia	5411.00N	13015.00W
Prince William Sound	USA	Alaska	6045.00N	14655.00W
Puget Sound	USA	Washington	4750.00N	12230.00W
Punta Blanca	Mexico	Baja Calif. Norte	2926.00N	11448.00W
Punta Eugenia	Mexico	Baja Calif. Sur	2753.30N	11505.00W
Qualicum Beach	Canada	British Columbia	4940.00N	12425.00W
Queen Charlotte Island	Canada	British Columbia	5300.00N	13430.00W
Queen Charlotte Sound	Canada	British Columbia	5120.00N	12900.00W
Queen Charlotte Strait	Canada	British Columbia	5038.00N	12700.00W
Quinault Indian Reservation	---	---	4730.00N	12400.00W
Rivers Inlet	Canada	British Columbia	5125.00N	12750.00W
Rescue Bay	Canada	British Columbia	5231.00N	12817.00W
Resurrection Bay	USA	Alaska	5948.00N	14930.00W
Rodriguez Seamount	---	---	3402.00N	12104.00W
Rosarito	Mexico	Baja Calif. Norte	3215.00N	11655.00W
Rude Canyon	---	---	5315.00N	17900.00E
Russell Fjord	USA	Alaska	6000.00N	13927.00W
Ryukyu Island	Japan	---	2620.00N	12830.00E
San Clemente Island	USA	California	3243.00N	11830.00W
San Cristobol Bay (Also Báhia San Cristobol)	Mexico	Baja Calif. Sur	2716.00N	11435.00W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
San Diego	USA	California	3239.90N	11715.50W
San Francisco	USA	California	3755.00N	12300.20W
San Francisco Bay	USA	California	3749.00N	12182.00W
San Hipolito Bay (Also Báhia San Hipólito)	Mexico	Baja Calif. Sur	2659.00N	11356.00W
San Juan Islands	USA	Washington	4838.00N	12309.10W
San Juan Seamount	---	---	3303.00N	12100.00W
San Juanico	Mexico	Baja Calif. Sur	2602.00N	11219.00W
San Luis Obispo Bay	USA	California	3509.60N	12045.60W
San Mateo Point	USA	California	3733.00N	12222.00W
San Miguel Island	USA	California	3405.00N	12022.00W
San Nicolas Basin	USA	---	3254.00N	11900.00W
San Nicolas Island	USA	California	3310.00N	11930.00W
San Pablo Bay	USA	California	3756.00N	12230.00W
San Pedro	USA	California	3345.00N	11819.00W
San Pedro Bay	USA	California	3340.00N	11810.00W
San Quintín Bay (Also Báhia San Quintín)	Mexico	Baja Calif. Norte	3030.00N	11603.00W
San Simeon	USA	California	3539.00N	12111.00W
Sanak Bank	USA	Alaska	5417.00N	16200.00W
Sanak Island	USA	Alaska	5431.00N	16240.00W
Santa Barbara	USA	California	3420.80N	11943.30W
Santa Barbara Channel	USA	California	3415.00N	12000.00W
Santa Catalina Island	USA	California	3315.00N	11825.00W
Santa Cruz Basin	USA	---	3343.00N	11933.00W
Santa Lucia Bank	USA	---	3450.00N	12120.00W
Santa Lucia Escarpment	---	---	3142.00N	12146.00W
Santa Monica Basin	USA	---	3344.20N	11851.00W
Santa Monica Bay	USA	California	3355.00N	11834.00W
Santa Cruz County	USA	California	3659.00N	12156.00W
Santa Cruz Island	USA	California	3355.00N	11940.00W
Santa Rosilia Bay (Also Báhia Santa Rosilia)	Mexico	Baja Calif. Norte	2845.00N	11425.00W
Scammons Lagoon (Also Laguna Ojo de Libre)	Mexico	Baja Calif. Sur	2750.00N	11416.00W
Sea of Japan	USSR/Japan	---	3900.00N	11500.00E
Seal Beach	USA	California	3344.30N	11806.00W
Sea of Okhotsk	USSR	---	5500.00N	14850.00E
Sebastion Vizcaino Bay (Also Báhia Sebastion Viscaino)	Mexico	---	2800.00N	11440.00W
Security Cove	USA	Alaska	5848.00N	16200.00W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
Seguam Pass	USA	Alaska	5210.00N	17300.00W
Selwyn Inlet	Canada	British Columbia	5250.00N	13139.00W
Semidi Islands	USA	Alaska	5610.00N	15647.00W
Seward Peninsula	USA	Alaska	6530.00N	16400.00W
Shelikof Strait	USA	Alaska	5730.00N	15500.00W
Shirsov Ridge	---	---	5820.00N	17000.00E
Shumagin Islands	USA	Alaska	5455.00N	16020.00W
Sidney Inlet	Canada	British Columbia	4835.50N	12317.50W
Sitka	USA	Alaska	5712.00N	13522.00W
Sitka Sound	USA	Alaska	5700.00N	13530.00W
Sitkinak Island	USA	Alaska	5633.00N	15410.00W
Sixty Mile Bank	USA	---	3204.00N	11813.00W
Skagit Bay	USA	Washington	4825.00N	12230.00W
Slime Bank	USA	---	5503.00N	16400.00W
Socorro Island (Also Isla Socorro)	USA	Alaska	1840.00N	11100.00W
Southern California Bight	USA	California	3350.00N	12000.00W
Spanish Canyon	---	---	4004.00N	12416.00W
Springfield Seamount	---	---	4804.00N	13010.00W
St. George Island	USA	Alaska	5632.00N	16925.00W
St. Lawrence Island	USA	Alaska	6345.00N	17030.00W
St. Matthew Canyon	---	---	5825.00N	17705.00W
St. Matthew Island	USA	Alaska	6036.00N	17242.00W
Stalemate Bank	USA	---	5300.00N	17000.00E
Stephens Passage	USA	Alaska	5740.00N	13355.00W
Stepovak Bay	USA	Alaska	5540.00N	15950.00W
Stikine River Flats	USA	Alaska	5631.00N	13224.00W
Stonewall Bank	---	---	4434.00N	12425.00W
Strait of Georgia	Canada	British Columbia	4917.00N	12350.00W
Strait of Juan De Fuca	USA/CAN	---	4818.00N	12400.00W
Stuart Channel	USA	Alaska	6332.30N	16233.00W
Siuslaw River	USA	Oregon	4400.00N	12405.00W
Sumner Strait	USA	Alaska	5608.00N	13355.00W
Sunset Bay	USA	Oregon	4320.00N	12422.75W
Sur Canyon	---	---	3605.00N	12207.00W
Surveyor Seamount	---	---	5600.00N	14310.00W
Sutwik Island	USA	Alaska	5637.00N	15712.00W
Swikshak Beach	USA	Alaska	5836.30N	15341.30W
Taholah	USA	Washington	4721.00N	12418.00W
Tananga Pass	USA	Alaska	5133.00N	17820.00W
Tanner Bank	---	---	3250.00N	11938.00W

APPENDIX A.--Continued.

Place	Nation	State or Province	Latitude	Longitude
Tillamook Bay	USA	Oregon	4530.00N	12355.00W
Tillamook Head	USA	Oregon	4557.00N	12400.00W
Todos Santos Bay (Also Báhia Todos Santos)	Mexico	Baja Calif. Norte	3150.00N	11645.00W
Tofino Inlet	Canada	British Columbia	4909.00N	12554.00W
Tomales Bay	USA	California	3810.00N	12255.00W
Thompson Seamount	---	---	4602.00N	12840.00W
Tortugas Bay (Also Báhia Tortugas)	Mexico	Baja Calif. Sur	2740.00N	11453.00W
Totten Inlet	USA	Washington	4708.00N	12300.00W
Trinidad Head	USA	California	4103.50N	12409.00W
Tsushima Island	Japan	---	3511.00N	13645.00E
Tufts Plain	---	---	4800.00N	14400.00W
Umpqua River (Bay)	USA	Oregon	4342.00N	12330.00W
Unalaska Island	USA	Alaska	5318.00N	16650.00W
Unimak Bight	USA	Alaska	5430.00N	16350.00W
Unimak Island	USA	Alaska	5445.00N	16500.00W
Unimak Pass	USA	Alaska	5420.00N	16450.00W
Vancouver	Canada	British Columbia	4905.00N	12258.00W
Vancouver Island	Canada	British Columbia	4930.00N	12530.00W
Vashon Island	USA	Washington	4723.30N	12222.40W
Victoria	Canada	British Columbia	4825.00N	12330.00W
Vizcaino Canyon	---	---	3941.00N	12430.00W
Washington	USA	---	4738.00N	12000.00W
Willapa Bay	USA	Washington	4637.00N	12404.60W
Winchester Bay	USA	Oregon	4341.00N	12411.00W
Wrangell	USA	Alaska	5628.00N	13210.00W
Yakutat Bay	USA	Alaska	5940.00N	14000.00W
Yankee Point	USA	California	3640.00N	12200.00W
Yaquina Bay	USA	Oregon	4445.00N	12405.00W
Yaquina Head	USA	Oregon	4440.60N	12404.70W
Zhemchug Canyon	---	---	5820.00N	17450.00W

APPENDIX B.--GLOSSARY OF TERMS USED IN SPECIES SYNOPSES.

ABYSSAL ZONE -- Open ocean bottom at depths of 4,000 to 6,000 meters.

ABYSSOPELAGIC -- Refers to the water column below 4,000 meters, the abyssopelagic zone.

ACANTHOCEPHALANS -- The phylum Acanthocephala lives its larval stages in the tissues of crustaceans and insects while its adult stage is spent in the intestines of vertebrates; spiny-headed worms.

ADDUCTOR MUSCLE -- A muscle, especially in molluscs, that pulls a part of the body toward the medium axis of the body. In bivalve molluscs, this muscle is used specifically to close the shells and hold them together.

ALEUTIAN PROVINCE -- A zoogeographical designation for faunal distributions that, based on minimum temperature requirements, extends from Puget Sound, Washington, to the Bering Strait.

ALEVIN -- The larval stage of trout and salmon that carries the yolk-sac during the time the fish are living under gravel.

ALGAE -- A collective, or general name, applied to a number of primarily aquatic, photosynthetic groups (taxa) of plants and plant-like protists. They range in size from single cells to large, multicellular forms like the giant kelps. They are the food base for almost all marine animals. Important taxa are the dinoflagellates (div. Pyrrophyta), diatoms (div. Chrysophyta), green algae (div. Chlorophyta), brown algae (div. Phaeophyta), and red algae (div. Rhodophyta). Cyanobacteria are often called blue-green algae, although blue-green bacteria is preferable.

AMPHIPODA -- An order of laterally compressed crustaceans with thoracic gills, no carapace, and similar body segments. Most are under one cm in length, and many are important members of the zooplankton. Some are bottom dwellers, and a few are parasitic; amphipods.

AMPHI-NORTH PACIFIC -- Referring to population distributions where a given species might occur on the east and west rims of the Pacific Ocean, but not on the northern rim.

ANADROMOUS -- Indicates a life cycle where breeding and early life is spent in fresh water, while the remainder is spent at sea.

ANESTROUS -- Refers to female mammals when in the nonreproductive phase of their cycles. They are usually unresponsive to males in this phase.

ANTHROPOGENIC -- Alluding to the effects of human activities.

ANTITROPICAL -- Refers to a distribution in both hemispheres, excluding the tropical region.

APPENDIX B.--Continued.

ARCTIC REGION -- The oceans above the zero degree celsius (0°C) winter isotherm. Along the Pacific coast, this corresponds approximately to 60° North latitude in the Bering Sea.

AREAL -- Refers to a measure of area.

ASCIDIAN -- A tunicate having a generalized saclike, cellulose body, such as the sea squirt.

AUSTRAL -- Relating to the south, or a terrestrial biogeographical zone between the transitional and tropical zones. This zone includes most of the United States through central Mexico in North America.

BATHYAL -- Refers to the zone of ocean bottom at depths of 200 to 4,000 meters, primarily on the continental slope and beyond.

BATHYMETRIC -- Refers to depth measurement, or to migrations from waters of one depth range to waters of another depth range.

BATHYPELAGIC -- Refers to the zone of ocean water from about 1,000 to 4,000 meters in depth.

BENTHIC -- Indicates a relationship to the ocean bottom (benthic realm), or to sessile and crawling animals of the sea floor.

BENTHOPELAGIC -- Refers to organisms that live above the ocean floor, but which feed on the bottom.

BENTHOPELAGIVORE -- A carnivore that feeds on the sea bottom while living in the pelagic realm above it.

BIGHT -- An inward bend or bow in the coastline.

BIOMASS -- The total weight of living tissues (wet or dried) of an organism, or collection of organisms of a species or trophic level from a defined area or volume.

BIVALVIA -- The most important commercial class of molluscs, also referred to as Pelecypoda. The shell is made of two halves (valves) connected by a hinge ligament. They are filter feeders and mostly sedentary. The class includes clams, oysters, scallops, and mussels.

BOREAL REGION -- The oceans between the 13°C winter isotherm and the 0°C winter isotherm. In neritic waters of western North America, it extends from Point Conception, California, to the Aleutian Islands.

BRACHYURAN -- A decapod crustacean; a true crab.

BRANCHIAL -- A structure or location associated with the gill.

BRYOZOA -- A minute, mosslike animal of the phylum Ectoprocta, forming branching colonies that reproduce by budding.

APPENDIX B.--Continued.

BYSSAL THREAD -- A tuft of filament, chemically similar to silk, serving to attach certain molluscs to a substrate.

CARNIVORE -- Any animal that feeds on other animals after killing them, or by eating them alive. See PARASITISM and PREDATION. Carnivore may refer specifically to members of the mammalian order Carnivora.

CERCARIA -- A free-swimming larval form of the class Trematoda.

CESTODE -- A class of parasitic, ribbonlike worms having no intestinal canal (e.g., the tapeworms).

CHAETOGNATHS -- The phylum Chaetognatha is characterized by a translucent, torpedo-shaped body that is quadrangular in cross section. These marine worms have lateral and caudal fins.

CHAETOPTERID POLYCHAETES -- The genus Chaetopterus lives in secreted parchment-like, U-shaped tubes; phylum Annelida.

CHELIPEDS -- First pair of legs in decapod crustaceans specialized for seizing and crushing.

CHEMOTAXIS -- A response movement by an animal either toward or away from a specific chemical stimulus.

CHORDATA -- A major phylum of animals including the subphyla Vertebrata, Cephalochordata, and Urochordata. All have three characteristics at some stage of the life cycle: pharyngeal gill slits, a notochord, and a dorsal, hollow nerve cord.

CILIA -- Hairlike processes of certain cells, capable of rhythmic beating that can produce locomotion or facilitate the movement of fluids within ducts.

CIRRI -- Flexible, threadlike tentacles or appendages of certain organisms.

CLINE -- A gradually varying distribution of a physical characteristic such as salinity or temperature along a gradient like depth or latitude. With populations, a similar distribution of a biological feature such as size or color.

COLONY -- Among invertebrates, a colony is a close association of individuals of a species which are often mutually dependent and in physical contact with other colony members. When used with vertebrates, a colony usually is a group brought together for breeding and rearing young.

COMMENSALISM -- A relationship between two species populations in which the population of one species is benefited or increased while the second population is unaffected.

APPENDIX B.--Continued.

COMMUNITY -- In ecology, a community is all of the various species populations in a defined area or habitat. Further restrictions are often made with modifiers such as the algal community, the invertebrate community, the benthic gastropod community, etc.

COMPETITION -- Interspecific competition involves populations of two or more species that use one or more limited resources such as food, attachment sites, protective cover, or dissolved ions. These interactions tend to have a depressing effect on the populations involved. Intraspecific competition is among members of a population for limited resources needed by the species for survival and reproduction. This form of competition includes resources involved in interspecific competition as well as resources like mates and territories, and is generally more intense because resource needs are essentially identical among conspecifics. See NICHE.

CONSPECIFIC -- Referring to individuals or populations of the same species.

CONTINENTAL SLOPE -- The steeply inclined ocean bottom that bridges a continental shelf and ocean basin.

CONTINENTAL SHELF -- An underwater plain that is part of a continental land mass and up to 200 meters below the sea. The shelf extends from the coastline to distances of a few miles to several hundred miles.

COPEPODA -- A subclass of crustaceans with about 4,500 species, including several specialized parasitic orders. The free-living species are small (one to several mm) with cylindrical bodies, one median eye, and two long antennae. One order is planktonic (Calanoida), one is benthic (Harpacticoida), and one has both planktonic and benthic species (Cyclopoida). Some head appendages form a complex filter apparatus in most species; these feed primarily on algae. Thoracic appendages are used for swimming or crawling on the bottom. This may be the most abundant group of animals on earth, and they are a major link in marine food webs.

CREPUSCULAR -- Relates to animals whose peak activity is between sunset and nightfall.

CRUSTACEA -- A large class of over 26,000 species of mostly aquatic arthropods with five pair of head appendages, including laterally opposed jaw-like mandibles and two pair of antennae. Most have well-developed compound eyes and variously modified two-branched body appendages. The body segments are often differentiated into a forward thorax and an abdomen. Some common members are crabs, shrimp, lobsters, copepods, amphipods, isopods, and barnacles.

CTENOPHORA -- A large phylum of mostly marine organisms with an oval, jellylike body bearing eight rows of comblike plates that aid in swimming; ctenophores.

APPENDIX B.--Continued.

CTENOPHORES -- The phylum Ctenophora is characterized by a free-swimming, biradially symmetrical body with eight rows of comb plates; comb jellies, sea walnuts.

CTENOSTOMATAN BRYOZOAN -- The order Ctenostomata is a member of the class Cymnolaemata; Alcyonidium.

CUMACEANS -- The order Cumacea (class Crustacea) is characterized by a small and shrimplike body with a short carapace and slender abdomen. Typically found burrowing in sand or mud sea bottoms.

DECAPOD -- (1) An order (Decapoda) of mostly marine Crustacea which includes the crab, shrimp, lobster, and crayfish. Appendages are mostly uniramous and the last five thoracic segments bear walking legs. (2) A suborder (Decapoda) of cephalopod molluscs characterized by ten appendages; squids and cuttlefish.

DECOMPOSERS -- Bacteria and fungi that ultimately break down dead organisms of all types to simple molecules and ions.

DEMERSAL -- Concerns swimming animals that live near sea bottom, or eggs that are denser than water and sink after being laid.

DEPOSIT FEEDER -- An animal that ingests soft sediments containing small organisms and detritus, or that filters organisms and dead material from such substrates.

DESICCATE -- To dry completely.

DETRITIVORE -- An organism that eats small particles of partially decomposed organic material (detritus). See DECOMPOSER.

DIATOMS -- Single-celled protistan algae of the division Chrysophyta that have intricate siliceous shells composed of two halves, like a box and lid. They range in size from about 10 to 200 micrometers, and the cells sometimes remain attached after divisions to form simple chains or colonies. These phytoplankters are the most numerous and important group among the ocean producers that form the food base for marine animals.

DIEL -- Relates to an activity cycle based on daily periods of light and dark. Circadian and diurnal are also used in relation to cycles of about 24 hours.

DIMORPHISM -- A condition where a population has two distinct physical forms (morphs). In sexual dimorphism, secondary sexual characteristics are markedly different (e.g., size, color, and behavior).

DINOFLAGELLATE -- A planktonic, unicellular protozoan typically bearing two flagella. Botanists and protozoologists have long belabored the classification of these organisms, as their characteristics resemble those of the plant and animal kingdom.

APPENDIX B.--Continued.

DIRECT DEVELOPMENT -- See EMBRYONIC DEVELOPMENT.

DISPERSAL -- In a more restricted sense, the movement of young animals away from their point of origin to locations where they will live at maturity. Generally, the spreading out of individuals throughout suitable habitat within or outside the population range.

DISTAL -- Relates to anotomical location. It is the farthest from the center or the point of attachment or origin; terminal. It is in contrast to proximal.

DISTRIBUTION -- (1) A species distribution is the pattern of its population or populations over its geographic range. See RANGE. (2) A population depth distribution is the proportion or number of all individuals, or those of various sizes or ages, at different depth levels. (3) A population age distribution is the proportion of individuals of each sex in various age classes. (4) Within a population, individuals may be distributed evenly, randomly, or in groups throughout suitable habitat.

DIURNAL -- Refers to daylight activities, or organisms most active during daylight. May also refer to 24-hour cycles. See DIEL.

ECDYSIS -- The periodic shedding of the exoskeleton to permit growth and change of form.

ECHINODERMATA -- A phylum of marine animals possessing a water vascular system, a hard, spiny skeleton, and radial symmetry, and including the sea stars and sea urchins; echinoderms.

ECTOPARASITE -- A parasite that attacks the host animal or plant from the outside. Feeding periods and/or attachment time may be brief compared to internal (endo-) parasites.

EELGRASS -- Seed plants of the genus Zostera that are adapted to living underwater while rooted in shallow sediments along coasts.

ELECTROPHORESIS -- A technique for separating mixtures of organic molecules, based on their different rates of travel in an electric field. It is somtimes used to identify different stocks of a species, through determining the "chemical signature" for muscle tissues from each stock.

EL NIÑO CURRENT -- An intermittent warm water current from the tropics that overrides the opposing cold current along the pacific coasts of North and South America (see gyre). This raises near-surface temperatures, depresses the thermocline, and often suppresses upwelling, resulting in drastic drops in primary productivity and consequent high mortality among marine animals. This is most pronounced on the coast of Peru. Effects are not as severe in North America, but northward shifts in distributions of species are common in El Niño years.

APPENDIX B.--Continued.

EMBRYONIC DEVELOPMENT -- The increase in cell number, body size, and complexity of organ systems as an individual develops from a fertilized egg until hatching or birth. In direct development, the individual is essentially a miniature of the adult at this time. It grows and gradually changes until maturity. In indirect development, the newly hatched differ greatly from the adult, and go through periodic, major changes (larval stages and metamorphosis).

EMIGRATION -- A permanent movement by some members of a population out of an area occupied by that population. See IMMIGRATION.

ENDEMIC -- Relates to a species or other taxonomic group that is native to a geographical region.

EPIBENTHIC -- On the sea bottom, as opposed to in the substrate.

EPIDERMAL -- Refers to the surface or outer layer of skin.

EPIFAUNA -- Animals living on the surface of the sea bottom.

EPIPELAGIC -- Refers to the upper sunlit zone of oceanic water where phytoplankton live and organic production takes place (approximately the top 150 meters). See EUPHOTIC.

EPIPHYTIC -- Relates to the growth habit of living on a plant (e.g., mosses growing on trees).

EPIPODAL -- A structure or location associated with the leg or foot; typically refers to arthropod anatomy.

EPIZOOTICS -- Refers to a rapidly spreading disease affecting a large number of animals; epidemic.

ESCARPMENT -- A sharp incline in topography as in a cliff or along the continental slope.

ESTUARY -- A partially enclosed body of water with an open connection to the sea, and one or more inflowing streams. There is a mixture of sea and freshwater (oligohaline or brackish). Typically, there is an influx of nutrients from the land resulting in high productivity, but with widely fluctuating physical conditions.

EUHALINE -- Water with salt concentrations of 30-40 ppt.

EUPHOTIC -- Refers to the upper levels of a water body where light penetrates and phytoplankton (algae) carry out photosynthesis (produce sugars from carbon dioxide and water using light energy). See EPIPELAGIC.

EURYHALINE -- Indicates a broad tolerance to salt concentrations.

APPENDIX B.--Continued.

EXTANT -- A species or other group of related organisms that is still in existence, not extinct.

EX-VESSEL VALUE -- The value assigned to the preprocessed weight of fish or shellfish.

FAUNA -- All of the animal species in a specified region.

FECUNDITY -- The potential of an organism to produce offspring. See REPRODUCTIVE POTENTIAL.

FILTER FEEDER -- Any of many species from a number of phyla that have adaptations for filtering small animals, plants, and detritus from water or fine sediments. Organs used include: gills in clams and oysters, baleen in whales, and specialized appendages in crustaceans and marine worms.

FLAGELLATE -- Refers to cells that possess organelles of motility or microorganisms that possess one or more flagellum used for locomotion.

FLORA -- All of the species of plants in a specified region.

FOOD WEB (CHAIN) -- The feeding relationships within a community of several to many species populations in a given area or region during a particular time period. Two broad types are recognized: grazing webs involve producers like algae, herbivores like copepods, and various combinations of carnivores and omnivores; detritus webs include scavengers, detritivores, and decomposers that feed on the dead remains of organisms from the grazing webs, as well as on their own dead. See TROPHIC LEVEL.

FORAMINIFERANS -- The order Foraminifera (class Sarcodina) is characterized by a shell composed of secreted calcium carbonate, silicon dioxide, or foreign material cemented with secretions. Pseudopodia project through pores in the shell.

FRESHWATER -- By definition, water that has a salt concentration of from 0.0 to 0.5 ppt.

FRY -- Very young fish. In trout and salmon, young that have just emerged from the gravel and alevin larval stage.

GAMETE -- A reproductive cell that is haploid and can unite with another gamete to form the cell (zygote) that develops into a new individual.

GASTRIC MILL -- A masticating chamber used to macerate, grind, and sieve food. Found in the stomach region of the crustaceans, it is a complex arrangement of teeth, ossicles, and setae

APPENDIX B.--Continued.

GASTROPODA -- This is the largest class of molluscs, most of whom are herbivores. Most have shells that are often spiraled, and they move on a flat, undulating foot. They scrape food with an organ analogous to a tongue (radula). The class includes terrestrial snails and slugs as well as aquatic relatives such as whelks, turbans, limpets, conchs, abalones, and nudibranchs.

GROUNDFISH -- Any species of fish that lives on or near the bottom, also called bottomfish.

GYRE -- An ocean current that follows a circular path around an ocean basin, clockwise in the Northern Hemisphere and the reverse in the southern. Two of these move along the coasts of North America, down on the west and up on the east.

HABITAT -- The particular type of place where an organism lives within a more extensive area or range. The habitat is characterized by its biological components and/or physical features (e.g., sandy bottom of the littoral zone, or on kelp blades within 10 m of the water surface).

HADAL ZONE -- The deepest bottoms of ocean trenches with depths of over 6,000 m.

HAPLOSPORIDIAN -- A unicellular protozoan occurring in vertebrate and invertebrate hosts, possibly bearing pseudopodia, but never flagella.

HECTOCOTYLIZED -- A hectocotylus is a specialized tip of one arm in the male cephalopod molluscs that facilitates the transfer of spermatophores to the mantle cavity of the female; also heterocotylized.

HERBIVORE -- Any type of organism that preys on living producers such as phytoplankton, large algae, or higher plants.

HERMAPHRODITIC -- Organisms having both male and female sex organs in the same individual.

HOLARCTIC -- The entire arctic realm including the Paleoarctic (Europe and Asia) and the Nearctic (North America). Also, the entire arctic region in oceanography.

HOOKA -- A modified scuba diving apparatus designed to receive air from the surface through a hose connected at the regulator.

HYDROZOA -- A class of coelenterate animals with a mostly nonmotile adult stage, characterized by a saclike body composed of two layers of cells and a mouth that opens directly into the body cavity; hydrozoan or hydroid.

HYPERSALINE -- Water with a salt concentration over 40 ppt.

APPENDIX B.--Continued.

HYPOLIMNION -- The zone of lake water below the thermocline.

IMMIGRATION -- A one-way movement of conspecifics into a population or breeding unit (deme or subpopulation). See EMIGRATION, MIGRATION, and RECRUITMENT.

INDIRECT DEVELOPMENT -- See EMBRYONIC DEVELOPMENT.

INFAUNA -- Animals living in the substrate of the sea bottom.

INNER SHELF -- The continental shelf nearest shore that extends from the mean low tide line to the 20 m isobath.

INSULAR -- Refers to characteristics of islands.

INTEROPAROUS -- Relates to organisms that have a number of reproductive periods during their lifespan.

INTERTIDAL -- The portion of the ocean floor exposed between highest and lowest tides.

ISOBATH -- A contour mapping line indicating a specified constant depth.

ISOPODA -- An order of about 4,000 species of dorsoventrally compressed crustaceans with abdominal gills and similar abdominal and thoracic segments. Terrestrial pillbugs and thousands of benthic, marine species are included. Most species are scavengers and/or omnivores, and a few are parasitic.

ISOTHERM -- A geographical contour line connecting points of equal mean temperature for a given time interval.

KINESIS -- A randomly directed movement by an animal in response to a sensory stimulus such as light, heat, or touch. When the response is directed, it is called a taxis. See CHEMOTAXIS.

LACUSTRINE -- Refers to something from or pertaining to lakes.

LAGOON -- A shallow pond or channel linked to the ocean.

LARVAE -- A developmental stage in the life cycle that is very different from the adult form in organisms with indirect development. See EMBRYONIC DEVELOPMENT.

LATERAL LINE -- A canal system with pressure sensors under the skin on both sides of the body of most fishes. The system connects indirectly with the inner ear and functions in sensing changes in water pressure due to movements in the water, including sound waves.

APPENDIX B.--Continued.

LITHODID CRAB -- The family Lithodidae is characterized by a short, fleshy abdomen folded forward below the body; stone crabs, Alaska king crab.

LITTORAL -- Refers to the area between the mean low and high tide levels. Water here is the littoral zone of the pelagic realm, and the bottom is the littoral zone of the benthic realm.

MANTLE -- The upper folded layer of skin in molluscs that extends over the sides enclosing the gills and most of the body in a cavity above the muscular foot. In squids and allies, the mantle is below the body and behind the tentacles (derived from the foot) due to the shift in the dorsal-ventral axis. The mantle produces the shell in species having them.

MEAN LOWER LOW WATER (MLLW) -- The arithmetic mean of the lower low water heights of a mixed tide observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). Only the lower low water of each pair of waters of a tidal day is included in the mean.

MEGALOPA -- A larval stage of marine crabs characterized by a developed carapace, thoracic appendages, and abdomen which is relatively adultlike.

MERISTIC -- Refers to the study of countable measurements, particularly counts of features such as vertebrae, fin rays, and scale rows. These are used in population comparisons and classification.

MESOHALINE -- Water with a salt concentration of 5-18 ppt.

MESOPELAGIC -- The open ocean zone from about 150-1,000 m where light penetration drops rapidly and ceases.

METAMORPHOSIS -- The process of changing from one body form to another distinctly different form during maturation in indirect development (e.g., tadpole changing to a frog). See EMBRYONIC DEVELOPMENT.

METRIC TON -- A unit of mass or weight equal to 2,204.6 lbs.

MICROSPORIDIAN -- The order Microsporidia is an intracellular parasite of fishes, arthropods, and other invertebrates; Nosema.

MIGRATION -- A back and forth movement by a population or subpopulation at regular intervals. Vertical migrations in the water column may be daily or seasonal within the same area. Depth migrations between deeper and shallower bottomed areas are usually seasonal and related to breeding. Many marine birds and mammals have seasonal latitudinal migrations also associated with breeding. See EMIGRATION, IMMIGRATION, RANGE, and RECRUITMENT.

MILT -- The seminal fluid and sperm of fish.

APPENDIX B.--Continued.

MOLT -- The general process of shedding and regrowing an outer covering at periodic intervals. Crustaceans and other arthropods molt their exoskeletons, grow rapidly, and produce larger exoskeletons. Most reptiles, birds, and mammals respectively molt skin, feathers, or fur.

MONOECIOUS -- See HERMAPHRODITIC.

MONOPHYLETIC -- Two or more groups (taxa) of organisms derived from a common ancestor.

MORPHOLOGY -- The appearance, form, and structure of organisms.

MORPHOMETRICS -- The study of comparative morphological measurements.

MORTALITY -- The proportion of deaths associated with a population or community of organisms caused by a variety of sources, including predation, disease, environmental conditions, etc.

MOTILE -- Capable of or exhibiting movement or locomotion.

MUTUALISM -- A type of interaction between populations of two species in which all or both derive benefit. Some authorities consider true mutualism to be obligatory for both species, while mutually beneficial relationships that are not essential for either species are classified as protocooperative (e.g., the blacksmith cleaning fish eats externally attached organisms from the sea bass).

MYSIDS -- The order Mysidacea (class Crustacea) is characterized by a carapace covering much of the thorax; opossum shrimp.

NACREOUS MATERIAL -- A calcarious secretion in the inner surface of the mantle of many molluscs. Foreign particles lodging between the inner shell surface and the mantle are covered by nacre, sometimes forming pearls.

NANNOPLANKTON -- Planktonic organisms smaller than 40 microns in diameter.

NATAL -- Relates to birth or hatching.

NEMATODA -- A phylum of roundworms; nematodes. They are found in practically all habitats, and may be the most abundant multicellular animals in marine sediments.

NEKTONIC -- Animals that are strong swimmers, live above the substrate in the water column, and can move independently of currents.

NEMERTEA -- A phylum of unsegmented, elongate marine worms having no body cavity, a protrusible proboscis, and living mostly in coastal mud or sand; nemerteans.

APPENDIX B.--Continued.

NERITIC -- Refers to the pelagic zone from the mean low tide level to the edge of the continental shelf. See INNER SHELF, LITTORAL, and OCEANIC ZONES.

NEUSTON -- Organisms that live at or on the water surface, often depending on surface tension for support. Like plankton down in the water column, they drift with currents.

NICHE -- The fundamental niche is the full range of abiotic and biotic factors under which a species can live and reproduce. The realized niche is the set of actual conditions under which a species, or a population of a species, exists, largely determined by interactions with other species.

NOCTURNAL -- Relates to night, or animals that are active at night.

NON-GRAVID -- A term describing the reproductive state for adult females not carrying eggs or young.

OCEANIC ZONES -- The part of the pelagic realm seaward of the edge of a continental shelf. See BATHYPELAGIC, EPIPELAGIC, ABYSSOPELAGIC, MESOPELAGIC, and NERITIC.

OLIGOHALINE -- Water with a salt concentration of 0.5 to 5.0 ppt., typical of estuarine conditions.

OLIGOTROPHIC -- Refers to water in which there is a basic lack of nutrients to support plant growth. Such water may also be characterized by indistinct dissolved oxygen stratification (especially in summer and winter in freshwater).

OMNIVORE -- An animal that eats both plants and animals.

ONTOGENETIC -- Referring to the history of development and growth of an organism.

OOCYTES -- The cells in ovaries that mature into eggs.

OPALESCENT -- Displaying colors like that of the opal; iridescent.

OPHIUROIDS -- The class Ophiuroidea (phylum Echinodermata) is characterized by highly flexible, slender arms that are sharply set off from the disc; brittle stars, basket stars.

OREGON PROVINCE -- A zoogeographical designation for faunal distributions that, based on minimum temperature requirements, extends from Puget Sound, Washington, to Point Conception, California; Oregonian.

OSTRACODS -- The subclass Ostracoda (class Crustacea) is characterized by a hinged bivalve carapace and adductor muscle; seed shrimp.

OVIGEROUS -- The condition of being ready to lay mature eggs

APPENDIX B.--Continued.

OVIPAROUS -- Animals whose eggs develop and hatch outside the body of the mother. See OVOVIVIPAROUS and VIVIPAROUS.

OVIPOSITION -- The process of placing eggs on or in specific places as opposed to the practice of randomly dropping or broadcasting them.

OVOVIVIPAROUS -- The condition where eggs are fertilized, developed, and hatched in the mother's body, but receive no nourishment from the mother. See OVIPAROUS and VIVIPAROUS.

PALP -- A jointed sensory organ attached to the head appendages of various arthropods; a fleshy sensory organ in the buccal cavity of various invertebrates.

PARASITISM -- An interspecific interaction where members of one species (parasite) feed on, or use the metabolic mechanisms of, the second (host). Unlike predators, parasites usually do not kill their hosts, although hosts may later die from secondary causes that are related to a weakened condition brought about by the interaction. Parasitism may also be fatal when high parasite density develops. Population effects are the same as in predation.

PARR -- Juvenile salmon and trout that have a series of dark, vertical bars on their sides and are only a few inches long.

PATHOGEN -- A microorganism or virus that can cause death.

PELAGIC -- Refers to the realm of ocean water above the benthic realm (bottom), or to organisms living in the water column in oceanic or neritic zones.

PELAGIVORE -- A carnivore that feeds in the water column.

PEREOPODS -- An appendage arising from a thoracic segment in crustaceans.

PHYLLOSOMA LARVAE -- A free-swimming larva of certain decapod crustaceans (e.g., California spiny lobster, Panulirus) which is depressed, wide, and transparent.

PHYLOGENY -- Refers to evolutionary relationships and lines of descent.

PHYTOPLANKTON -- Microscopic plants and plant-like protists (algae) of the epipelagic and neritic zones that are the base of offshore food webs. They drift with currents, but usually have some ability to control their level in the water column. See ALGAE and DIATOMS.

PISCIVOROUS -- A carnivorous animal that eats fish.

PLANKTIVOROUS -- An animal that eats phytoplankton and/or zooplankton.

PLANKTON -- See PHYTOPLANKTON and ZOOPLANKTON.

APPENDIX B.--Continued.

PLEOPODS -- Biramous appendages of the subclass Malacostraca used to create a current of oxygenated water in contact with the body; swimmerets.

POLYCHAETE -- A group of segmented, mostly marine, annelid worms bearing bristled, fleshy appendages on most segments.

POLYCLADID FLATWORM -- The order Polycladida is a member of the marine class Turbellaria.

POLYHALINE -- Water with a salt concentration between 18 and 30 ppt.

POPULATION -- A group of individuals of the same species occupying a defined area during a given time. Environmental barriers may divide the population into local breeding units (demes) with restricted immigration and interbreeding between the localized units. See SPECIES, SUBSPECIES, and SUBPOPULATION.

PPT -- Parts per thousand.

PRECOCIAL -- Developmentally advanced.

PREDATION -- An interspecific interaction where an animal species (predator) feeds on another animal or plant species (prey) while the prey are alive or after killing them. The relationship tends to be positive (increasing) for the predator population and negative (decreasing) for the prey population. See PARASITISM, SYMBIOTIC, CARNIVORE, and TROPHIC LEVEL.

PRIMIPAROUS -- Bearing young or producing eggs for the first time.

PRODUCTION -- Gross primary production is the amount of light energy converted to chemical energy in organic compounds by autotrophs like algae. The amount left after respiration is net primary production and is usually expressed as biomass or calories/unit area/unit time. Net production for herbivores and carnivores is based on the same concept, except that chemical energy from food, not light, is used and partially stored for life processes. Efficiency of energy transfers between trophic levels is seldom greater than 10%; therefore, organisms at high trophic levels have only a fraction of the energy available to them that was stored in plant biomass. After respiration loss, net production goes into growth and reproduction, or is passed to the next trophic level (e.g., human harvest of commercial fish). See FOOD WEB and TROPHIC LEVEL.

PROKARYOTIC -- Refers to cells that have nuclear bodies but lack chromosomes, nucleoli, and nuclear membranes.

PROMISCUOUS -- Mating behavior characterized by indiscriminate association with more than one mate.

APPENDIX B.--Continued.

PROTANDRY -- A type of hermaphroditism in which the same gonads in an individual produce eggs and sperm at different times during its lifespan. This individual is then regarded as a different sex. The condition is fairly common among fish and invertebrates.

PROTISTAN -- A varied unicellular organism of the general taxonomic category Protista, which possesses characteristics from such groups as the algae, fungi, and protozoans.

PROTOZOA -- A varied group of either free-living or parasitic unicellular flagellate and amoeboid organisms.

PYCNOCLINE -- A graded or gradual change in water density with depth.

RADULA -- A toothed belt in the buccal cavity of most molluscs that is used to scrape food particles from a surface, or modified otherwise to serve a variety of feeding habits.

RANGE -- (1) The geographic range is the entire area bounded by the extremes of locations where a species is known to occur or to have occurred (historical range). The range of a species may be continuous, or it may have unoccupied gaps between populations (discontinuous distribution). (2) Some populations, or the entire species, may have different seasonal ranges. These may be overlapping, or they may be widely separated with intervening areas that are at most briefly occupied during passage on relatively narrow migration routes. (3) Home range refers to the local area that an individual or group uses for a long period or life. See DISTRIBUTION and TERRITORY.

RECRUITMENT -- The addition of new members to a population or stock through maturation of juveniles and immigration.

RED TIDE -- A reddish discoloration of sea waters caused by a bloom in populations of red protozoan flagellates. A large accumulation of metabolic by-products from these organisms is toxic to fish and other marine life and is responsible for mortality.

REDD -- A depression in gravel dug by female salmon and trout where spawning is completed. The eggs are then covered with gravel by sweeping movements of the tail.

REPRODUCTIVE POTENTIAL -- The total offspring possible for a female of a given species if she lives to the maximum reproductive age. This is found by multiplying the number of possible reproductive periods by the average number of eggs or offspring produced by females of each age class. This potential is seldom realized, but this and the age of first reproduction, or generation time, determine the maximum rate of population increase under ideal conditions.

RHEOTAXIS -- A response movement by an animal toward or away from stimulation by a water current.

APPENDIX B.--Continued.

RHIZOCEPHALAN BARNACLE -- The order Rhizocephala is a specialized parasite on crabs. The parasite possesses absorptive rootlike structures that penetrate the host body, no shell, no appendages, and no digestive tract.

RIVERINE -- Relates to activity or presence in streams.

ROE -- The egg mass of fish within the ovarian membrane.

SAN DIEGO PROVINCE -- A zoogeographical designation for faunal distributions that, based on minimum temperature requirements, extends from Point Conception, California, to Magdalena Bay, Baja California Sur; San Diegan.

SCAVENGER -- Any animal that feeds on dead animals or scraps and remains of animals killed by other predators. See DECOMPOSER and DETRITIVORE.

SEAMOUNT -- An undersea mountain whose top is below sea level, in contrast to an island.

SEDENTARY -- Regards animals that remain in a restricted area, or those that have little ability to move. See SESSILE.

SEMELPAROUS -- Refers to animals that have a single reproductive period during their lifespan.

SERPULID POLYCHAETES -- The genus Serpula lives in secreted calcareous shells and possesses numerous, sometimes ornate gill filaments at the anterior end; phylum Annelida.

SESSILE -- Refers to organisms that are attached to the substrate or are nonmotile. See SEDENTARY.

SHOAL -- (1) A sand bar in a body of water that is exposed at low tide. (2) An area of shallow water. (3) A group of fish (school). (4) As a verb, to collect in a crowd, group, or school.

SIPHONOPHORES -- Members of the order Siphonophora (class Hydrozoa, phylum Coelenterata) live pelagic marine colonies composed of several kinds of polyps. The medusae remain attached to the parent generation; Velella.

SIPHONS -- Tubes of clams and other bivalves that are used to bring water with food items and oxygen to the gills and back to the water column above the burrows.

SLOUGH -- A shallow mudflat that is exposed at low tide, often with a stream passing through. Sloughs often border estuaries.

SMOLT -- Juvenile salmon or anadromous trout in the process of adapting and moving to the ocean.

APPENDIX B.--Continued.

SOMATIC -- Refers to bodily parts or cells exclusive of the reproductive cells.

SPAT -- Juvenile bivalve molluscs which settle from the water to the substrate to begin adult life.

SPAWN -- With fish, to lay eggs. This usually occurs during mating, but may occur later in species with internal fertilization; the released eggs.

SPECIES -- One or more populations whose members interbreed when in contact and produce fertile offspring, and have the potential to interbreed when not currently in contact. See POPULATION, SUBPOPULATION, and SUBSPECIES.

SPERMATHECAE -- A small sac in the reproductive system of female invertebrates that receives sperm from the female.

SPERMATOPHORE -- A gelatinous packet containing sperm that is produced by some male animals in a number of taxonomic groups.

SPIROCHAETE -- A spiral-shaped, non-flagellated bacteria of the order Spirochaetales. This varied group can be free-living, parasitic, or disease-causing.

SPIT -- A long, narrow sand bar partially connected to the shore. See SHOAL.

SPOROCYST -- A simple larval stage of parasitic trematode worms. Contact with the host causes a metamorphosis from an earlier stage to this one.

STENOHALINE -- A narrow tolerance range for salt concentration, in contrast to euryhaline.

STIPE -- A thickened, stemlike structure in kelps bearing other structures such as blades; basal portion of the thallus or plant body of alga.

STOCK -- A mature breeding population that is, or could be, exploited by man. See POPULATION and SUBPOPULATION.

SUBLITTORAL -- Refers to the benthic zone along the coast that is not uncovered by mean low tides and that extends to depths of about 200 m.

SUBPOPULATION -- A breeding unit (deme) of a defined population. These may differ little genetically, and are not taxonomic units. See SUBSPECIES. Subpopulations may intergrade with some interbreeding, or they may occupy a common seasonal range prior to the mating season. Populations from the same breeding area may form subpopulations based on hatching year in salmonids and others when each year-class breeds only once at a specific age. See STOCK and POPULATION.

APPENDIX B.--Continued.

SUBSPECIES -- A taxonomic class assigned to populations and/or subpopulations when interbreeding (gene flow) with one or more other subspecies is limited, and there are significant differences in some combination of characteristics between subspecies (e.g., appearance, anatomy, ecology, physiology, and behavior). When successful interbreeding does not occur when the groups are in contact under natural conditions, reproductive isolation is complete, and the groups are considered distinct species. Classification of such groups that are not naturally in contact is based on the comparative study and judgement of phylogenists. A second epithet for each subspecies is added to the binomial for the species (e.g., Sebastes alutus alutus and Sebastes alutus paucispinosus). See SPECIES, POPULATION, and SUBPOPULATION.

SUBTIDAL -- See SUBLITTORAL.

SUPRALITTORAL -- Refers to the splash zone of land adjacent to the sea that is above the mean high tide level.

SUSPENSION FEEDER -- An animal that feeds on minute organisms and organic debris that is suspended in the water, directly or by filtration.

SYLLID POLYCHAETES -- Asexually budding marine worms of the phylum Annelida.

SYMBIOTIC -- Refers to a relationship between two different species that may be positive, negative, or neutral in its effects on the populations of each. See COMPETITION, MUTUALISM, PARASITISM, and PREDATION.

TAXONOMY -- A system of arranging animals and plants into related groups based on common features (e.g., structure, embryology, biochemistry).

TEMPERATE REGION -- Oceanic waters between the 13°C winter isotherm and the 20°C winter isotherm. The temperate region of the neritic zone on the Pacific coast of North America extends from Point Conception, California, to Magdalena Bay, Baja California Sur.

TEMPORAL -- Used regarding activities, developmental stages, and distributions as they relate to daily, seasonal, or geologic time periods.

TERRITORY -- An area occupied and used by an individual, pair, or larger social group, and from which other individuals or groups of the species are excluded, often with the aid of auditory, olfactory, and visual signals as well as threat displays and outright combat.

TEST -- A rigid calcareous exoskeleton found in the echinoderm class Echinoidea (e.g., sea urchins, sand dollars).

THERMOCLINE -- A relatively narrow layer of water where temperature decreases rapidly with depth. This layer separates warmer upper water from colder lower water. Little water or solute exchange occurs across the thermocline while it is maintained by solar heating of the upper layers.

APPENDIX B.--Continued.

TREMATODE -- A large class of parasitic flatworms with one or more muscular, external suckers, such as a fluke.

TRIPLOIDY -- The occurrence of three times the haploid number of chromosomes. When genetically engineered, randomly occurring traits may be selected for commercial applications. For example, Pacific oyster experiences a degradation in the quality of the flesh associated with spawning. Non-reproducing, triploid cultures avoid this seasonal problem.

TROCHOPHORE -- A molluscan larval stage (except in Cephalopoda) following gastrulation (embryonic stage characterized by the development of a simple gut). It is commonly ciliated, biconically shaped, and free-swimming and establishes an evolutionary link between annelids and molluscs in that both groups display important similarities during this life stage.

TROPHIC LEVEL -- The level from which an organism gets its energy, based on degree of removal from the sun. At the first level are autotrophs or producers (e.g., kelp and diatoms); second level are herbivores (e.g., copepods and snails); third level and above are carnivores (e.g., salmon and seals). Omnivores feed at the second and at least one higher level, and many animals feed at several levels. Decomposers and detritivores feed at all trophic levels. See FOOD WEB and PRODUCTION.

TROPICAL REGION -- Oceanic waters between the 20°C winter isotherms in the southern and northern hemispheres. Tropical neritic waters along the west coasts of North and South America extend from the southern tip of Baja California, Mexico, to about lat. 5°S. along the coast of Peru.

TUNICATES -- The common name for the subphylum Urochordata (phylum Chordata). Characterized by a cylindrical to globular body with a secreted cuticular tunic and two prominent distal openings. A notochord is present at some stage of development and may persist through the adult stage; ascidians, salps, and sea squirts.

TURBELLARIA -- A class of mostly aquatic, non-parasitic flatworms appearing leaf-shaped and covered with cilia; turbellarian.

UPWELLING -- The process where prevailing seasonal winds create surface currents that move cold water with organic nutrients from ocean depths and sediments back to the euphotic or epipelagic zone. This breaks down the thermocline and allows increased production by algae, resulting in very valuable fisheries.

VELIGER -- A developmental stage common in molluscs, which forms after the trochophore larva. This is a stage of considerable differentiation when adult features such as the shell and foot become apparent.

APPENDIX B.--Continued.

VIVIPAROUS -- Eggs are retained in the reproductive system and the young are released live.

WATER COLUMN -- The water from the surface to the bottom at a given point.

YEAR-CLASS -- All animals in a population hatched or born in the same year at about the same time, also known as a cohort. Strong year-classes result when there is a high early survival rate, and the reverse is true for weak classes. The effects on population size and structure may persist for years in species with longer lifespans. Variation in strength often affects the fisheries. See DISTRIBUTION and STOCK.

ZOEA -- One of several in a series of early larval stages of various marine crabs and shrimp displaying many appendages and long dorsal and anterior spines.

ZOOPLANKTON -- Animal members of the plankton. Most range from microscopic to about an inch in length. They feed on phytoplankton and each other. Some groups included are protozoa, jellyfish, comb jellies, arrowworms, lower chordates, copepods, water fleas, krill, and the larvae of many fish and invertebrates that are not planktonic as adults. They have little or no ability to swim against currents and drift passively with the currents, primarily in the upper or epipelagic zone.